इंटरनेट मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

“जानने का अधिकार, जीने का अधिकार”
Mazdoor Kisan Shakti Sangathan
“The Right to Information, The Right to Live”

“पुराने को छोड नये के तरफ”
Jawaharlal Nehru
“Step Out From the Old to the New”

IS 15675 (2006): Flow measurement of natural gas and fluid by orifice plate meters [PGD 26: Weights and Measures]

“ज्ञान से एक नये भारत का निर्माण”
Satyanarayan Gangaram Pitroda
“Invent a New India Using Knowledge”

Act Number 22 of 2005
The Indian Parliament
RIGHT TO INFORMATION

Made Available By
Public.Resource.Org

“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”
Bhartṛhari—Nītiśatakam
“Knowledge is such a treasure which cannot be stolen”

BLANK PAGE

BRUTUM FULMEN

IGNORANTIA
JURIS
NON EXCUSAT

PROTECTED BY COPYRIGHT

भारतीय मानक

ओरोफिस प्लेट मीटर द्वारा प्राकृतिक गैस अथवा फ्ल्यूड का प्रवाह मापन

Indian Standard

FLOW MEASUREMENT OF NATURAL GAS AND FLUIDS BY ORIFICE PLATE METERS

ICS 75.160.30; 75.180.30

© BIS 2006

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

June 2006

Price Group 12

Weights and Measures Sectional Committee, PG 26

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Weights and Measures Sectional Committee had been approved by the Production and General Engineering Division Council.

This standard is taken for measuring the gas consumption at the bulk suppliers as well as at the users' end, when the gas is supplied through the pipelines. In order to meet the requirement of bulk supplier and large consumer, this standard has been formulated for accuracy of metering system and regulation of gas at different delivery point to fulfill the consumer satisfaction. This standard determines the flow by means of measurement of the differential pressure by orifice meter. The differential pressure is induced by the flow of gas through a thin plate with a sharp square-edge-opening which is circular and concentric with the pipeline. While measuring the flow rate, this standard indicates the differential pressure, gas temperature, pressure density, viscosity etc.

In preparing the standard considerable assistance has been derived from the following publication:

ISO 5167-2 : 2003 'Measurement of fluid flow by means of pressure differential devices inserted in circular-cross section conduits running full — Part 2 : Orifice plates'

AGA 3 'American Gas Authority Report for Orifice Plate Meters'

Wherever comma (,) has been given in a formula or table in between numerals, it should be read as decimal (.) mark.

Annexes A, B are for information only.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

CONTENTS

Title			*Page*
1.	SCOPE	...	1
2.	REFERENCE	...	1
3.	PRINCIPLE OF THE METHOD OF MEASUREMENT AND COMPUTATION	...	1
4.	SYMBOLS/NOMENCLATURE	...	1
5.	DESCRIPTIONS AND REQUIREMENTS	...	2
6.	METER TUBE	...	8
7.	MATERIALS	...	8
8.	PRESSURE MEASUREMENT	...	8
9.	PRESSURE TAPPINGS	...	10
10.	COEFFICIENTS AND CORRESPONDING UNCERTAINTIES OF ORIFICE PLATES	...	12
11.	INSTALLATION REQUIREMENTS	...	15
12.	FLOW CONDITIONERS	...	18
13.	MARKING	...	25
ANNEX A	TABLES OF DISCHARGE COEFFICIENTS AND EXPANSIBILITY (EXPANSION) FACTORS	...	26
ANNEX B	FLOW CONDITIONERS	...	37

Indian Standard

FLOW MEASUREMENT OF NATURAL GAS AND FLUIDS BY ORIFICE PLATE METERS

1 SCOPE

1.1 This standard specifies the geometry and method of use (installation and operating conditions) of orifice plates when they are inserted in a conduit running full to determine the flow rate of the fluid flowing in the conduit. This standard also provides background information for calculating the flow rate and is applicable in conjunction with the requirements.

1.2 This standard is applicable to primary devices having an orifice plate used with flange pressure tappings. Other pressure tappings such as vena contracta and pipe tappings used with orifice plates are not covered by this standard. This standard is applicable only to a flow which remains subsonic throughout the measuring section and where the fluid can be considered as single phase. It is not applicable to the measurement of pulsating flow. It does not cover the use of orifice plates in pipe sizes less than 50 mm or more than 1 000 mm, or for pipe Reynolds number below 5 000.

1.3 This standard is used for custody transfer of natural gas and fluids.

2 REFERENCE

The following standard is indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced standard (including any amendment) applies.

Standard No.	*Title*
ISO 5167-1 : 2003	Measurement of fluid flow by means of pressure differential devices inserted in circular-cross section conduits running full — Part 1 : General principles and requirements

3 PRINCIPLE OF THE METHOD OF MEASUREMENT AND COMPUTATION

3.1 The principle of the method of measurement is based on the installation of an orifice plate into a pipeline in which a fluid is running full. The presence of the orifice plate causes a static pressure difference between the upstream and downstream sides of the plate. The mass flow rate, q_m can be determined as follows:

$$q_m = \frac{C}{\sqrt{1-\beta^4}}\ \varepsilon \frac{\pi}{4} d^2 \sqrt{2\,\Delta p \rho_1}$$

where ρ is the fluid density at the temperature and pressure for which volume is stated.

3.2 The uncertainty limits can be calculated using the procedure given in **8** of ISO 5167-1. Computation of the mass flow rate, which is a purely arithmetic process, can be performed by replacing the different terms on the right hand side of the above equation by their numerical values.

Similarly, the value of volume flow rate, q_V is calculated from:

$$q_V = \frac{q_m}{\rho}$$

where ρ is the fluid density at the temperature and pressure for which the volume is stated.

The coefficient of discharge, C, is dependent on the Reynolds number, R_e, which is itself dependent on q_m and is to be obtained by iteration (*see* Annex A of ISO 5167-1) for guidance regarding the choice of the iteration procedure and initial estimates.

3.3 The diameters d and D mentioned in the formula are the values of the diameters at working conditions. Measurements taken at any other conditions shall be corrected for any possible expansion or contraction of the orifice plate and the pipe due to the values of the temperature and pressure of the fluid during the measurement.

It is necessary to know the density and the viscosity of the fluid at the working conditions. In the case of a compressible fluid, it is also necessary to know the isentropic exponent of the fluid at working conditions.

4 SYMBOLS/NOMENCLATURE

This standard reflects orifice meter application to fluid flow measurement with symbols in general technical use. Following symbols have been used in this standard.

Symbol *Represented Quantity*

A : speed-of-sound

C : orifice plate discharge coefficient

$C_d\,(FT)$: flange tap orifice plate discharge coefficient

$\Delta C\,(FT)/C$: percent difference between baseline C_d and installation effect C_d

d : orifice plate bore diameter calculated at flowing temperature, T_f

d_m : orifice plate bore diameter measured at temperature, T_m

d_r : orifice plate bore diameter calculated at reference temperature, T_r

D : meter tube internal diameter calculated at flowing temperature, T_f

D_i : published meter tube internal pipe diameter

DL : meter tube length downstream of orifice plate in multiple of published internal pipe diameters

D_m : meter tube internal diameter measured at T_m

D_n : nominal pipe diameter

D_r : meter tube internal diameter calculated at reference temperature, T_f

e : orifice plate bore thickness

E : orifice plate thickness

f : frequency

°C : temperature in degrees Centigrade

l : recommended length of gauge line

NPS : nominal pipe size

ΔP : orifice plate differential pressure

ΔP_{avg} : average orifice plate differential pressure

ΔP_{rms} : root mean square of the fluctuating differential pressure

ΔP_{ri} : instantaneous orifice plate differential pressure

P_f : static pressure of the fluid at the pressure tap

°R : temperature in degrees Rankine

Q_v : volume flow rate

Q_{rv} : mass flow rate

R_a : absolute roughness average

R_e : Reynolds number

T_f : temperature of fluid at flowing conditions

T_m : temperature of the orifice plate and/or meter tube at time of diameter measurements

T_r : reference temperature (45°C) of orifice plate bore diameter and/or meter tube internal diameter

Symbol *Represented Quantity*

UL_1 : $UL - UL_2$

UL_2 : meter tube length (UL) from flow conditioner exit to orifice plate in multiples of published internal pipe diameters

α : linear coefficient of thermal expansion

α_1 : linear coefficient of thermal expansion of the orifice plate material

α_2 : linear coefficient of thermal expansion of the meter tube material

β : ratio of orifice plate bore to meter tube internal diameter (d/D) calculated at flowing temperature, T_f

β_m : ratio of orifice plate bore to meter tube internal diameter (d_m/D_m) calculated at temperature, T_m

β_r : ratio of orifice plate bore to meter tube internal diameter (d_r/D_r) calculated at reference temperature, T_f

ε : orifice plate bore eccentricity

θ : orifice plate bevel angle

ρ : fluid density

5 DESCRIPTIONS AND REQUIREMENTS

The descriptions are given to emphasize the particular meaning of the terms as used in this standard.

5.1 Orifice Plate

The primary element is defined as the orifice plate, the orifice plate holder with its associated differential pressure sensing taps, the meter tube, and flow conditioner, if used.

5.2 General

The axial plane cross-section and symbols of a standard orifice plate is shown in Fig. 1, 2, 3 and 4.

Care shall be taken in the design of the orifice plate and its installation to ensure that plastic buckling and elastic deformation of the plate, due to the magnitude of the differential pressure or of any other stress, do not cause the slope of the straight line to exceed 1 percent under working conditions.

5.3 General Shape

The part of the plate inside the pipe shall be circular and concentric with the pipe centre line. The faces of the plate shall always be flat and parallel.

The orifice plate is defined as a thin square-edged plate with a mechanical circular bore, concentric with the meter tube ID, when installed.

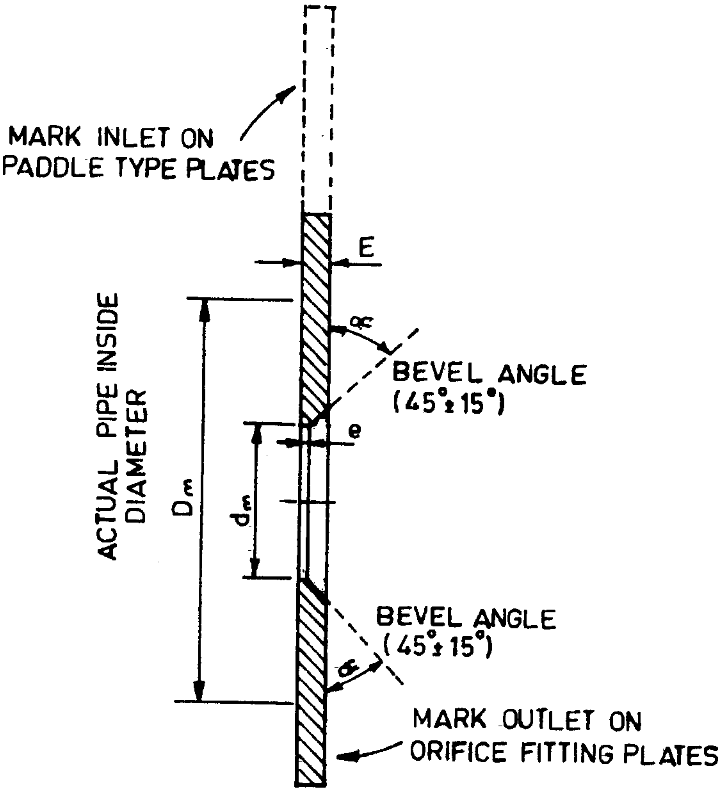

MARK INLET ON PADDLE TYPE PLATES
E
ACTUAL PIPE INSIDE DIAMETER
Dm
α
BEVEL ANGLE (45° ± 15°)
e
dm
BEVEL ANGLE (45° ± 15°)
α
MARK OUTLET ON ORIFICE FITTING PLATES

FIG. 1 SYMBOLS FOR ORIFICE PLATE DIMENSIONS

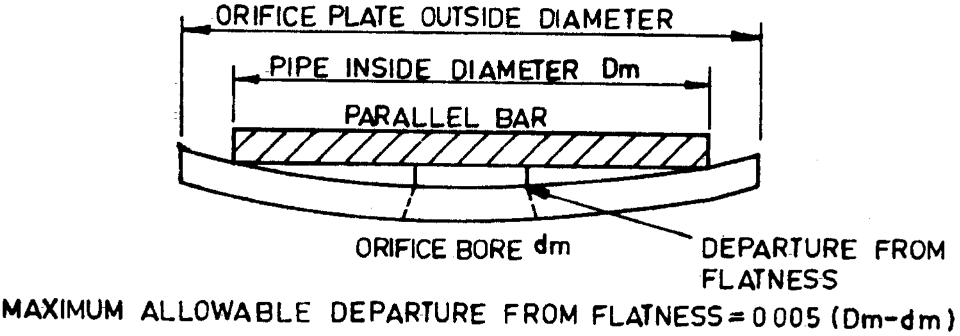

ORIFICE PLATE OUTSIDE DIAMETER
PIPE INSIDE DIAMETER Dm
PARALLEL BAR
ORIFICE BORE dm
DEPARTURE FROM FLATNESS
MAXIMUM ALLOWABLE DEPARTURE FROM FLATNESS = 0 005 (Dm-dm)

FIG. 2 ORIFICE PLATE DEPARTURE FROM FLATNESS
(MEASURED AT EDGE OF ORIFICE BORE AND WITHIN INSIDE PIPE DIAMETER)

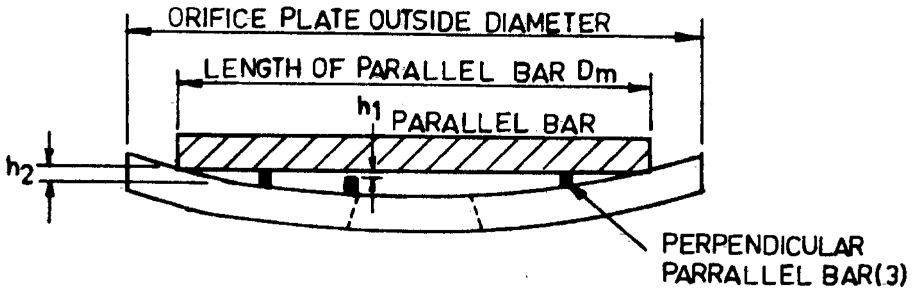

ORIFICE PLATE OUTSIDE DIAMETER
LENGTH OF PARALLEL BAR Dm
h1
PARALLEL BAR
h2
PERPENDICULAR PARRALLEL BAR(3)

FIG. 3 ALTERNATE METHOD FOR DETERMINATION OF ORIFICE PLATE DEPARTURE FROM FLATNESS
(DEPARTURE FROM FLATNESS = $h_2 - h_1$)

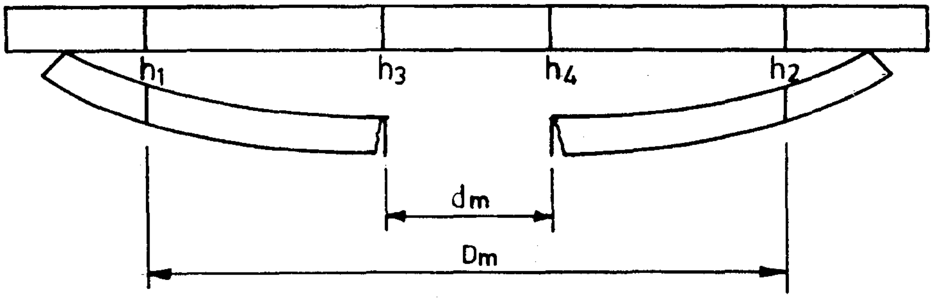


FIG. 4 MAXIMUM ORIFICE PLATE DEPARTURE FROM FLATNESS

5.4 Orifice Plate Faces

The upstream and downstream faces of the orifice plate shall be flat. Deviations from flatness on the orifice plate of less than or equal to 1 percent of dam height (that is, 0.025 mm per mm of dam height) under non-flowing conditions are allowed. The dam height can be calculated from the formula $(D_m - d_m)/2$. This criterion for flatness applies to any two points on the orifice plate within the dimensions of the inside diameter of the pipe. The departure from flatness is illustrated in Fig. 1, 2 and 3.

The surface roughness of the upstream and downstream faces of the orifice plate shall have no abrasions or scratches visible to the naked eye that exceeds 1.25 microns R_a.

The orifice plate surface roughness may be verified by using an electronic-averaging-type surface roughness instrument with a cutoff value of not less than 0.75 mm. Other surface roughness devices (for example, a visual comparator) are acceptable for determining orifice plate surface roughness, if the same repeatability and reproducibility as those of the electronic-averaging-type surface roughness instrument can be demonstrated.

Due care shall be exercised to keep the plate clean and free from accumulation of dirt, ice, grit, grease, oil, free liquid and other extraneous materials, to the extent feasible, by instituting a regular inspection schedule (daily, weekly, monthly, quarterly, etc, depending on the service conditions). Damage and/or accumulation of extraneous materials on the orifice plate may result in a greater uncertainty for the orifice plate coefficient of discharge [C_d (FT)]. After any inspection of the plate, it shall be thoroughly cleaned (free from accumulations as stated above) prior to being placed back in service.

5.5 Roughness Average (R_a)

The roughness average (R_a) used in this standard is the arithmetic average of the absolute values of the measured profile height deviation taken within the sampling length and measured from the graphical centreline of the surface profile.

5.6 Thickness *E* and *e*

The thickness *e* of the orifice shall be between $0.005D$ and $0.02D$.

5.6.1 The difference between the values of *e* measured at any point on the orifice shall not be greater than $0.001D$.

The thickness *E* of the plate shall be between *e* and $0.05D$.

However, when 50 mm $\leq D \leq$ 64 mm, a thickness *E* up to 3.2 mm is acceptable.

If $D \geq$ 200 mm, the difference between the values of *E* measured at any point of the plate shall not be greater than $0.001D$. If $D <$ 200 mm, the difference between the values of *E* measured at any point of the plate shall not be greater than 0.2 mm.

5.6.2 The inside surface of the orifice plate bore shall be in the form of a constant-diameter cylinder having no defects, such as grooves, ridges, pits, or lumps, visible to the naked eyes. The length of the cylinder is the orifice plate bore thickness (*e*).

The minimum allowable orifice plate bore thickness (*e*) is defined by $e \geq 0.01d_r$ or $e > 0.125$, whichever is larger.

The maximum allowable value of the orifice plate bore thickness (*e*) is defined by $e \leq 0.02D_r$ or $e \leq 0.125d_r$ whichever is smaller, but *e* shall not be greater than the maximum allowable orifice plate thickness (*E*).

5.6.3 The minimum, maximum, and recommended values of orifice plate thickness (*E*) for types 304 and 316 stainless steel orifice plates are given in Table 1.

5.6.4 Maximum allowable differential pressures for the recommended orifice plate thickness given in Table 3 are for operating temperatures not exceeding 65°C, the orifice plate and/or holding device manufacturer shall be contacted for specific

Table 1 Orifice Plate Thickness and Maximum Allowable Differential Pressure Based on the Structural Limit

(*Clauses* 5.6.3, 5.6.5, 5.6.6 *and* 5.8)

Nominal Pipe Size (NPS) mm	**Inside Pipe Diameter** mm	**Orifice Plate Thickness, *E*** mm			**Maximum Allowable ΔP (Water Column)**	
		Minimum	Maximum	Recommended	Orifice Fitting	Orifice Flange
(1)	(2)	(3)	(4)	(5)	(6)	(7)
50.80	42.85	2.92	3.30	3.18	1 000	1 000
	49.25	2.92	3.30	3.18	1 000	1 000
	52.50	2.92	3.30	3.18	1 000	1 000
76.20	58.42	2.92	3.30	3.18	1 000	1 000
	66.65	2.92	3.30	3.18	1 000	1 000
	73.66	2.92	3.30	3.18	1 000	1 000
	77.93	2.92	3.30	3.18	1 000	1 000
101.60	80.06	2.92	3.30	3.18	1 000	1 000
	87.33	2.92	3.30	3.18	1 000	1 000
	97.18	2.92	3.30	3.18	1 000	1 000
	102.26	2.92	3.30	3.18	1 000	1 000
152.40	124.38	2.92	4.14	3.18	345	1 000
	131.75	2.92	4.14	3.18	345	1 000
	146.33	2.92	4.88	3.18	345	1 000
	154.05	2.92	4.88	3.18	345	1 000
203.20	193.68	2.92	6.45	6.35	1 000	1 000
	202.72	2.92	8.10	6.35	1 000	1 000
	205.00	2.92	8.10	6.35	1 000	1 000
254.00	242.87	2.92	8.10	6.35	570	1 000
	254.51	2.92	8.10	6.35	570	1 000
	257.45	2.92	8.10	6.35	570	1 000
304.80	288.90	4.45	9.63	6.35	285	1 000
	303.23	4.45	10.11	6.35	285	1 000
	307.09	4.45	10.11	6.35	285	1 000
406.40	373.08	4.45	12.45	9.53	465	1 000
	381.00	4.45	12.70	9.53	465	1 000
	381.64	4.45	12.70	9.53	465	1 000

NOTES

1 Maximum allowable differential pressure is limited to 1 000 min of water column which is the limit of the coefficient of discharge database.

2 Maximum allowable differential pressure is calculated for worst-case diameter ratio (typically β = 0.55-0.65).

3 The maximum differential pressure applies to stainless steel plates at a maximum temperature of 65°C, and for the recommended plate thickness.

4 For single-or dual-chamber fittings, the orifice plate seal ring was assumed to deflect under symmetric conditions without plastic deformation. As such, the effect on the seal ring was not investigated.

5 Especially at very high differential pressures, the user should carefully consider the associated thermodynamic effects, such as temperature change resulting from the Joule-Thompson effect as the stream passes through the orifice, and the limits on ΔPLP_f, in particular, at low pressures. The sudden reduction of pressure will result in temperature and density changes.

information on deflection for a given diameter ratio, temperature, orifice plate material, orifice plate holder, and differential pressure.

5.6.5 The use of an orifice plate thickness other than the recommended thickness is acceptable in either new or existing orifice plate holding devices as long as the thickness is within the maximum and minimum range shown in Table 1; and the orifice plate eccentricity, bore thickness, differential pressure tap hole, and expansion-factor (*see* Table 2) pressure-ratio tolerances and limits are satisfied.

Table 2 Linear Coefficient of Thermal Expansion

Sl No.	Material	Linear Coefficient of Thermal Expansion (α) mm/mm °C
(1)	(2)	(3)
i)	Type 304 and 316 stainless steel	0.000 422 91
ii)	Monel	0.000 363 474
iii)	Carbon Steel	0.000 283 464

NOTE — Temperature conditions other than those stated in refer to the American Society for Metals, Metals Handbook.

5.6.6 For incompressible fluids, the maximum differential pressure across the plate is limited by the structural integrity of the fitting design. The maximum differential pressure shall be limited to those shown in Table 1. If the maximum differential pressure is to exceed the limits specified, the manufacturer shall be consulted for allowable maximum pressure for the fitting design. In addition, the flowing conditions downstream of the orifice plate must remain above the local vapour pressure of the flowing fluid.

5.6.7 Orifice fitting manufacturers shall be consulted to determine the maximum allowable differential pressure during the changing of orifice plates under flowing conditions. The high forces associated with using high differential pressures may make it difficult to remove the plate, and may possible result in damage to the orifice plate or fitting.

5.6.8 The use of high differential pressures ($\Delta P/\Delta P_f$ > 18 mm of water-column where the ΔP) is in cm of water at 50°C and P_f is, in mm of water-column will result in expansion factor uncertainties in excess of 0.1 percent.

5.6.9 Operators shall be aware, for a given orifice plate size, that when there is a wide swing from high to low flows, significant measurement errors will occur during the low-flow period if the orifice plate remains unchanged. Generally, operation between 10 percent to 90 percent of the calibrated differential span is considered good practice. Rangeability can also be increased using today's digital (electronic) transmitters. The effects on the accuracy of transducers and/or transmitters used for wide range shall be evaluated *versus* savings on installation cost.

5.6.10 For the full range of orifice plate thickness, the maximum allowable orifice plate differential pressure can be obtained.

Higher differential pressures will result in higher meter-run gas velocities and higher permanent pressure losses. It is recommended that the gas velocities be evaluated on an individual installation basis for such things as noise, erosion, and thermo well vibration. The meter run velocity is dependent on several different factors, and each individual user will have different practices and limits on velocity.

5.6.11 When the orifice plate thickness (E) exceeds the orifice bore thickness (e), a bevel is required on the downstream side of the orifice bore.

NOTE — Existing orifice plates, whose edge thickness meets the value defined by $e < 0.033D_m$, need not to be rebeveled unless reconditioning is required for other reasons.

For ease in machining, the next smaller values of e are 0.8 mm may be used.

5.6.12 Orifice plate bored that demonstrate any convergence from inlet to outlet are unacceptable. Bi-directional flow through an orifice plate with bore thickness (e) that exceeds the limits specified in this table is outside of the scope of this standard.

5.7 Angle of Bevel, α (*see* Fig. 1)

If the thickness E of the plate exceeds the thickness e of the orifice, the plate shall be beveled on the downstream side. The beveled surface shall be well finished. The angle of bevel α shall be 45° ± 15°.

5.8 Orifice Plate Bore Diameter (d, d_m, d_r)

The calculated orifice plate bore diameter (d) is the internal diameter of the orifice plate measuring aperture (bore) computed at flowing temperature (T_f). The calculated orifice plate bore diameter (d) is used in the flow equation for the determination of flow rate. The diameter (d) shall in all cases be greater than or equal to 12.5 mm. The diameter ratio, d/D shall be always greater than or equal to 0.10 and less than equal to 0.75.

The measured orifice plate bore diameter (d_m) is the measured internal diameter of the orifice plate measuring aperture at the temperature of the orifice plate (T_m) at the time of bore diameter measurements.

The reference orifice plate bore diameter (d_r) is the internal diameter of the orifice plate measuring aperture at reference temperature (T_r), calculated the reference orifice plate bore diameter is the certified or stamped orifice plate bore diameter.

The measured orifice bore diameter (d_m) is defined as the mean (arithmetic average) of four or more evenly spaced diameter measurements of the inlet edge. None of the four or more diameter measurements may vary from the mean value by more than the tolerances given in Table 3.

Table 3 Roundness Tolerance for Orifice Plate Bore Diameter, d_m

(*Clauses* 5.6.4 *and* 5.8)

Sl No.	Orifice Bore Diameter mm	Tolerance ± mm
(1)	(2)	(3)
i)	≤ 6.35[1]	0.007 62
ii)	6.375 4-9.525[1]	0.010 16
iii)	9.550 4-12.7[1]	0.012 7
iv)	12.725 4-15.875	0.012 7
v)	15.900 4-19.05	0.012 7
vi)	19.075 4-22.225	0.012 7
vii)	22.250 4-25.4	0.012 7
viii)	> 25.4	0.012 7 mm per mm of diameter

---

[1] Use of diameters below 11.43 mm is not prohibited, but may results in uncertainties greater value.

The minimum, maximum, and recommended values of orifice plate thickness (E) for types 304 and 316 stainless steel orifice plates are given in Table 1.

Maximum allowable differential pressures for the recommended orifice plate thickness given in Table 1 are for operating temperatures not exceeding 65°C, the orifice plate and/or holding device manufacturer shall be contacted for specific information on deflection for a given diameter ratio, temperature, orifice plate material. Orifice plate holder, and differential pressure.

The use of an orifice plate thickness other than the recommended thickness is acceptable in either new or existing orifice plate holding devices as long as the thickness is within the maximum and minimum range shown in Table 1; and the orifice plate eccentricity, bore thickness, differential pressure tap hole, and expansion-factor pressure-ratio tolerances and limits are satisfied.

For incompressible fluids, the maximum differential pressure across the plate is limited by the structural integrity of the fitting design. The maximum differential pressure shall be limited to those shown in Table 1. if the maximum differential pressure is to exceed the limits specified, the manufacturer shall be consulted for allowable maximum pressure for the fitting design. In addition, the flowing conditions downstream of the orifice plate must remain above the local vapour pressure of the flowing fluid.

Orifice fitting manufacturers shall be consulted to determine the maximum allowable differential pressure during the changing of orifice plates under flowing conditions. The high forces associated with using high differential pressures may make it difficult to remove the plate, and may possible result in damage to the orifice plate or fitting.

The use of high differential pressures ($\Delta P/\Delta P_f$ > 18 mm of water-column, where the ΔP is in mm of water at 20°C and P_f is in kg/m) will result in expansion factor uncertainties in excess of 0.1 percent.

Operators shall be aware, for a given orifice plate size, that when there is a wide swing from high to low flows, significant measurement errors will occur during the low-flow period if the orifice plate remains unchanged. Generally, operation between 10 percent to 90 percent of the calibrated differential span is considered good practice. Rangeability can also be increased using today's digital (electronic) transmitters. The effects on the accuracy of transducers and/or transmitters used for wide range shall be evaluated *versus* savings on installation cost.

For the full range of orifice plate thickness, the maximum allowable orifice plate differential pressure can be applicable.

It is recommended that the gas velocities be evaluated on an individual installation basis for such things as noise, erosion, and thermowell vibration. The meter-run velocity is dependent on several different factors, and each individual user will have different practices and limits on velocity. Therefore, the allowable maximum differential pressures, do not consider meter-run gas velocity. Higher differential pressures will result in higher meter-run gas velocities and higher permanent pressure losses.

5.9 Orifice Plate Bore Edge

The upstream edge of the orifice plate bore shall be square and sharp. The orifice plate bore edge is considered too dull for accurate flow measurement if the upstream edge reflects a beam of light when viewed without magnification or if the upstream edge shows a beam of light when checked with an orifice edge gauge.

5.10 Orifice Plate Holder

The orifice plate holder is defined as a pressure containing piping element, such as a set of orifice flanges or an orifice fitting, used to contain and position the orifice plate in the piping system.

6 METER TUBE

The meter tube is defined as the straight section of pipe, including all segments that are integral to the orifice plate holder, upstream and downstream of the orifice plate.

6.1 Meter Tube Internal Diameter (D, D_i, D_m, D_r)

The calculated meter tube internal diameter (D) is the inside diameter of the upstream section of the meter tube computed at flowing temperature (T_f) The calculated meter tube internal diameter (D) is used in the diameter ratio and Reynolds number equations.

The measured meter tube internal diameter (D_m) is the average inside diameter of the upstream section of the meter tube measured 25 mm upstream of the adjacent face of the orifice plate and at the temperature of the meter tube (T_m) at the time of internal diameter measurements.

The reference meter tube internal diameter (D_r) is the inside diameter of the upstream section of the meter tube calculated at the reference temperature (T_r). The reference meter tube internal diameter is the certified meter tube internal diameter.

The upstream and downstream edges of the orifice plate bore shall be free from defects visible to the naked eye, such as flat spots, feathered texture, roughness, burrs, bumps, nicks, and notches.

If there is any doubt about whether the edge has sufficient quality for accurate metering, the orifice plate shall be replaced.

The orifice plate temperature shall be recorded at the time the bore diameter measurements are made. These measurements shall be made under thermally stable conditions; that is diameter at reference temperature (T_r) and can be determined using the following equation:

$$d_r = d_m[1+ \alpha_1 (T_r - T_m)]$$

where

α_1 = linear coefficient of thermal expansion for the orifice plate material (*see* Table 2),

d_r = orifice plate bore diameter calculated at reference temperature (T_r),

d_m = orifice plate bore diameter measured at T_m,

T_m = temperature of the orifice plate at time of diameter measurements, and

T_r = reference temperature of the orifice plate bore diameter.

NOTE — α_1, T_m and T_r shall be in consistent units. For the purpose of this standard T_r is assumed to be ambient temperature.

The orifice plate bore in diameter (d_r) calculated at T_r is the reference diameter used to calculate the bore diameter (d) at flowing conditions.

6.2 Diameter Ratio (β, β_m, β_r)

The diameter ratio (β) is defined as the calculated orifice plate bore diameter (d) divided by the calculated meter tube internal diameter (D).

The diameter ratio (β_m) is defined as the measured orifice plate bore diameter (d_m) divided by the measured meter tube internal diameter (D_m).

The diameter ratio (β_r) is defined as the reference orifice plate bore diameter (d_r) divided by the reference meter tube internal diameter (D_r).

7 MATERIALS

7.1 The materials employed for gas metering installation shall be capable of withstanding the gas composition under the all conditions that may be experienced over the lifetime of the metering.

7.2 Any meter tube pipe not exceeding 600 mm diameter shall be seamless wherever possible. Above this size, longitudinally S.A.W. (submerged arc welded) pipe shall be used.

7.3 The pipe shall be inspected internally to ensure that it complies to the dimensional and surface finish tolerances specified in AGA 3.

7.4 Flanges shall be manufactured form forged steel. The flanges in the vicinity of the orifice plate shall be match-bored to the pipe and also dwelled/retained in such a manner that there is no internal step in the meter tube.

7.5 On orifice fittings, the internal diameter, surface finish, concentricity and position and condition of the pressure tap holes shall be carefully manufactured and inspected to ISO/AGA or an equivalent standard.

7.6 The orifice plate shall be manufactured from stainless steel plate. The petrology of the plate should meet the requirements of AGA 3. The plate may be manufactured from any material and in any way provided that it is remains in accordance with the forging description during the flow measurement.

8 PRESSURE MEASUREMENT

8.1 Tap Hole

A tap hole is a hole drilled radially in the wall of the meter tube or through the orifice fitting and perpendicular to the centreline of the meter tube or orifice plate holder, the inside edge of which is flush and without any burrs.

8.2 Flange Taps

Flange taps are a pair of tap holes positioned as follows:

a) Upstream tap centre is located 25.4 mm upstream of the nearest plate face;

b) Downstream tap centre is located 25.4 mm downstream of the nearest plate face; and

c) Upstream and downstream taps must be in the same radial position.

8.3 Differential Pressure ($\Delta P, \Delta P_{avg}, \Delta P_{rms}, \Delta P_t$)

The differential pressure (ΔP) is the static pressure difference measured between the upstream and the downstream flange taps.

The average differential pressure (ΔP_{avg}) is a time mean of the static pressure difference measured between the upstream and the downstream flange taps.

The instantaneous differential pressure (ΔP_t) is a single measurement of ΔP at any instance in time.

The root mean square differential pressure(ΔP_{rms}) is the square root of the sum of squares of the difference between the instantaneous differential pressure (ΔP_t) and the time mean differential (ΔP_{avg}).

8.4 Permanent Pressure Drop

The permanent pressure drop is significant because the energy has been lost to transport the fluid through the pipeline. Approximate values of the permanent pressure loss ΔP *versus* β ratio for the concentric, square-edged, flange tapped orfice meter are given below:

β	*Losses as a percent of* ΔP
0.20	95
0.30	90
0.40	85
0.50	75
0.60	65
0.70	50
0.75	45

Example:

If the user chooses to use a β of 0.30 at ΔP of 10 000 mm of water column then the permanent pressure loss would be approximately 90 percent of 10 000 mm of water column which is about 9 000 mm of water column (about 90 kPa).

If the user chooses to use a β of 0.50 at ΔP of 2 500 mm of water column, then the permanent pressure loss would be approximately 75 percent of 2 500 mm of water column, which is about 1 875 mm of water column (about 90 kPa).

8.5 Temperature Measurement (T_f, T_m, T_r)

The temperature (T_f) is the flowing fluid temperature measured at the designated location.

In flow measurement, the temperature sensing device is inserted in the flowing stream to obtain the flowing temperature. However, if the fluid velocity is higher than 25 percent of the fluid sound speed at the point of measurement, corrections for the increase in temperature due to dynamic effects will have to be applied. Care shall be taken to ensure that the temperature sensing elements are coupled to the flowing stream and not to the steel in the metal tube. This practice is recommended for all orifice meter installations. The sensed temperature is assumed to be static temperature of the flowing fluid.

The temperature (T_m) is the measured temperature of the orifice plate and/or the meter tube at the time of the diameter measurements.

The temperature (T_r) is the reference temperature used to determine the reference orifice plate bore diameter (d_r) and/or the reference internal meter tube diameter (D_r).

$$\text{Maximum departure from flatness} = \frac{[h_3 + h_4] - [h_1 + h_2]}{2}$$

An estimation of suitable sharpness can be made by comparing the orifice plate bore edge with the bore edge of a properly sharp reference orifice plate of the same nominal diameter. The orifice plate bore edge being evaluated should feel and look the same as the edge of the reference orifice plate.

8.6 Bi-directional Plates

8.6.1 If the orifice plate is intended to be used for measuring reverse flows, the following requirements shall be ensured:

a) plate shall not be bevelled;

b) two faces shall comply with the specifications for the upstream face;

c) thickness E of the plate shall be equal to the thickness e of the orifice consequently, it may be necessary to limit the differential pressure to prevent plate distortion; and

d) two edges of the orifice shall comply with the specifications for the upstream edge.

8.6.2 For orifice plates with D and $D/2$ tappings, two sets of upstream and downstream pressure taps shall be provided and used according to the direction of the flow.

8.6.3 *Material and Manufacture*

The plate may be manufactured from any material and in any way, provided that it is and remains in accordance with the foregoing description during the flow measurements.

9 PRESSURE TAPPINGS

9.1 General

For each orifice plate, at least one upstream pressure tapping and one downstream pressure tapping shall be installed in one or other of the standard locations, that is as *D* and *D*/2, flange or corner tappings.

A single orifice plate may be used with several sets of pressure tappings suitable for different types of standard orifice meters, but to avoid mutual interference, several tappings on the same side of the orifice plate shall be offset by at least 30°

The location of the pressure tappings characterizes the type of standard orifice meter.

9.2 Orifice Plate with *D* and *D*/2 Tappings or Flange Tappings

9.2.1 The spacing of a pressure tapping is the distance between the centreline of the pressure tapping and the plane of a specified face of the orifice plate. When installing the pressure tappings, due account shall be taken of the thickness of the gaskets and/or sealing material.

9.2.2 For orifice plates with *D* and *D*/2 tappings (*see* Fig. 3), the spacing l_1 of the upstream pressure tapping is nominally equal to *D*, but may be between 0.9*D* and 1.1*D* without altering the discharge coefficient.

The spacing l_2 of the downstream pressure tapping is nominally equal to 0.5*D* but may be between the following values without altering the discharge coefficient:

a) between 0.48*D* and 0.52*D* when $\beta \leq 0.6$; and

b) between 0.49*D* and 0.51*D* when $\beta > 0.6$.

Both l_1 and l_2 spacings are measured from the upstream face of the orifice plate.

For orifice plates with flange tappings (*see* Fig. 5), the spacing l_1 of the upstream pressure tapping is nominally 25.4 mm and is measured from the upstream face of the orifice plate.

The spacing l_2 of the downstream pressure tapping is nominally 25.4 mm and is measured from the downstream face of the orifice plate.

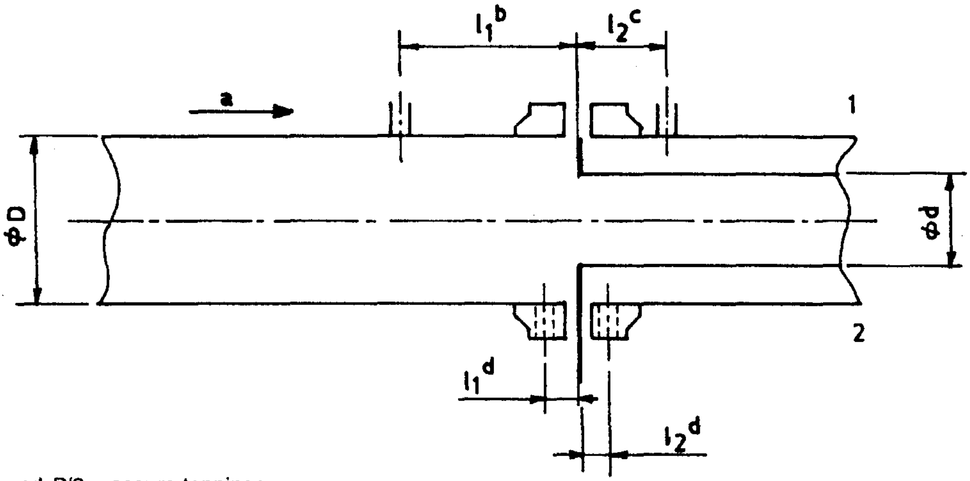
These upstream and downstream spacings l_1 and l_2 may be within the following ranges without altering the discharge coefficient:

a) 25.4 mm: ± 0.5 mm when $\beta > 0.6$ and $D < 150$ mm; and

b) 25.4 mm: *t* ± mm in all other cases, that is, $\beta \leq 0.6$, or $\beta > 0.6$ but 150 mm $\leq D \leq 1000$ mm.

The centreline of the tapping shall meet the pipe centreline at an angle as near to 90° as possible, but in every case within 3° of the perpendicular.

At the point of break-through, the hole shall be circular. The edges shall be flush with the internal surface of the pipe wall and as sharp as possible. To ensure the elimination of all burrs or wire edges



KEY

1 *D* and *D*/2 pressure tappings

2 flange tappings:

a = direction of flow

$b = l_1 = D \pm 0.1D$

$c = l_2 = 0.5D \pm 0.2D$ for $\beta \leq 0.6$

$0.5D \pm 0.1D$ for $\beta > 0.6$

$d = l_1 = l_2'$ = (25.4 ± 0.5) mm for $\beta > 0.6$ and $D < 150$ mm

= (25.4 ±1) mm for $\beta \leq 0.6$

= (25.4 ± 1) mm for $\beta > 0.6$ and 150 mm $\leq D \leq$ 1 000 mm

FIG. 5 SPACING OF PRESSURE TAPPING FOR ORIFICE PLATE WITH *D* AND *D*/2 TAPPING OR FLANGE TAPPINGS

at the inner edge, rounding is permitted but shall be kept as small as possible and, where it can be measured, its radius shall be less than one-tenth of the pressure tapping diameter. No irregularity shall appear inside the connecting hole, on the edges of the hole drilled in the pipe wall or on the pipe wall close to the pressure tapping.

Conformity of the pressure tappings with the requirements specified at above and may be judged by visual inspection.

The diameter of pressure tappings shall be less than $0.13D$ and less than 13 mm.

No restriction is placed on the minimum diameter, which is determined in practice by the need to prevent accidental blockage and to give satisfactory dynamic performance. The upstream and downstream tappings shall have the same diameter.

The pressure tappings shall be circular and cylindrical over a length of at least 2.5 times the internal diameter of the tapping, measured from the inner wall of the pipeline.

The centrelines of the pressure tappings may be located in any axial plane of the pipeline.

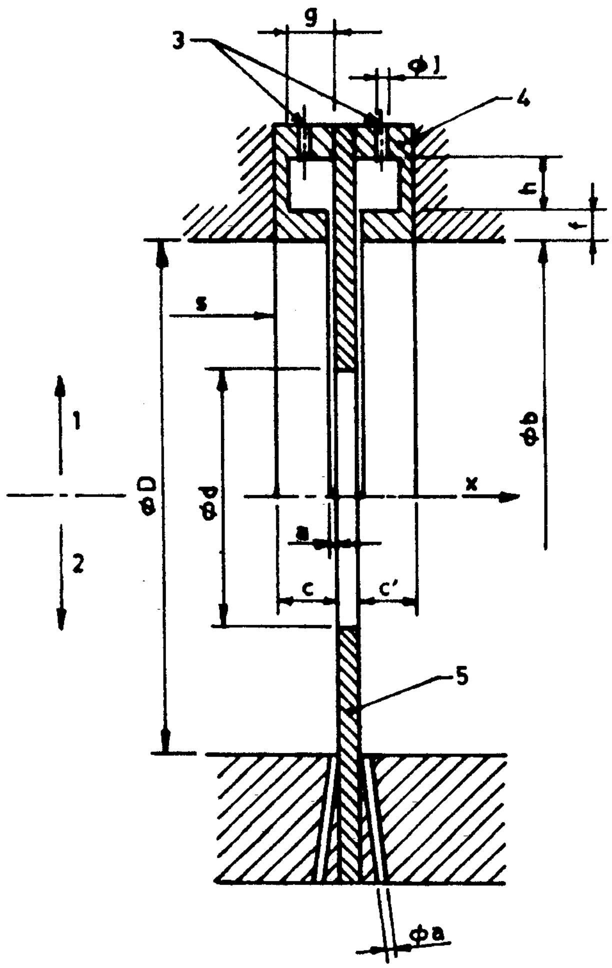
The axis of the upstream tapping and that of the downstream tapping may be located in different axial planes, but are normally located in the same axial plane.

9.3 Orifice Plate with Corner Tappings

9.3.1 The spacing between the centrelines of the tappings and the respective faces of the plate is equal to half the diameter or to half the width of the tappings themselves, so that the tapping holes break through the wall flush with the faces of the plate.

9.3.2 The pressure tappings may be either single tappings or annular slots. Both types of tappings may be located either in the pipe or its flanges or in carrier rings as shown in Fig. 6.

The diameter a of a single tapping and the width a of annular slots are specified below. The minimum diameter is determined in practice by the need to prevent accidental blockage and to give satisfactory



KEY

1 — carrier ring with annular slot
2 — individual tappings
3 — pressure tappings
4 — carrier ring
5 — orifice plate
x = direction of flow
f = thickness of the slot
c = length of upstream ring
c' = length of the downstream ring
b = diameter of the carrier ring
a = width of annular slot or diameter of single tapping
s = distance from upstream step to carrier ring
g. h = dimensions of the annular chamber
ϕj = chamber tapping diameter

FIG. 6 CORNER TAPPINGS

dynamic performance. For clean fluids and vapours:

a) for $\beta \leq 0.65 : 0.005D > a \leq 0.03D$; and
b) for $\beta > 0.65 : 0.01D \leq a \leq 0.02D$.

If $D < 100$ mm, a value of a up to 2 mm is acceptable for any β.

For any values of β:

a) for clean fluids: 1 mm $\leq a \leq$ 10 mm;
b) for vapours, in the case of annular chambers: 1 mm $\leq a \leq$ 10 mm; and
c) for vapours and for liquefied gases, in the case of single tappings: 4 mm $\leq a \leq$ 10 mm.

The annular slots usually break through the pipe over the entire perimeter, with no break in continuity. If not, each annular chamber shall connect with the inside of the pipe by at least four openings, the axes of which are at equal angles to one another and the individual opening area of which is at least 12 m^2.

If individual pressure tappings, as shown in Fig. 4, are used, the centreline of the tappings shall meet the centreline of the pipe at an angle as near to 90° as possible.

If there are several individual pressure tappings in the same upstream or downstream plane, their centrelines shall form equal angles with each other.

The pressure tappings shall be circular and cylindrical over a length of at least 2, 5 times the internal diameter of the tappings measured from the inner wall of the pipeline.

The upstream and downstream pressure tappings shall have the same diameter.

The internal diameter b of the carrier rings shall be greater than or equal to the diameter D of the pipe, to ensure that they do not protrude into the pipe, but shall be less than or equal to $1.04D$. Moreover, the following condition shall be met:

$$\frac{b-D}{D} \times \frac{c}{D} \times 100 < \frac{0.1}{0.1+2.3\,\beta^4}$$

The lengths c and c' of the upstream and downstream rings (*see* Fig. 6) shall not be greater than $0.5D$.

The thickness f of the slot shall be greater than or equal to twice the width of the annular slot. The area of the cross-section of the annular chamber, g_h, shall be greater than or equal to half the total area of the opening connecting this chamber to the inside of the pipe.

All surfaces of the ring that are in contact with the measured fluid shall be clean and shall have a well-machined finish. The surface finish shall meet the pipe roughness requirements.

The pressure tappings connecting the annular chambers to the secondary devices are pipe-wall tappings, circular at the point of break-through and with a diameter j between 4 mm and 10 mm.

The upstream and downstream carrier rings need not necessarily be symmetrical in relation to each other, but they shall both conform with the preceding requirements.

The diameter of the pipe shall be measured, the carrier ring being regarded as part of the primary device. This also applies to the distance s shall be measured from the upstream edge of the recess formed by the carrier ring.

10 COEFFICIENTS AND CORRESPONDING UNCERTAINTIES OF ORIFICE PLATES

10.1 Limits of Use

Standard orifice plates shall only be used in accordance with ISO 5167-1 under the following conditions.

For orifice plates with corner or with D and $D/2$ pressure tappings:

a) $d \geq 12.5$ mm;
b) 50 mm $\leq D \leq$ 1 000 mm;
c) $0.1 \leq \beta \leq 0.75$;
d) $Re_D \leq 5\,000$ for $0.1 \leq \beta \leq 0.56$; and
e) $Re_D \geq 16\,000\,\beta^2$ for $\beta > 0.56$.

For orifice plates with flange tappings:

a) $d \geq 12.5$ mm;
b) 50 mm $\leq D \leq$ 1 000 mm; and
c) $0.1 \leq \beta \leq 0.75$.

Both $Re_D \geq 5\,000$ and $Re_D \geq 170\,\beta^2 D$

where D is expressed in millimetres.

The pipe internal roughness shall satisfy the following specification if the uncertainty values in this part of ISO 5167-1 are to be met, L_e. the value of the arithmetical mean deviation of the roughness profile, R_a, shall be such that $10^4 R_a/D$ is less than the maximum value given in Table 4 and greater than the minimum value given in Table 5. The discharge coefficient equation was determined from a database collected using pipes whose roughness is known; the limits on R_a/D were determined so that the shift in discharge coefficient due to using a pipe of a different roughness should not be so great that the uncertainty value. Information regarding pipe roughness may be found of ISO 5167-1.

Table 4 Maximum Value of $10^4 R_a/D$

(*Clause* 10.1)

Sl No.	β	$R_e D$								
		10^4	3×10^4	10^5	3×10^5	10^6	3×10^6	10^7	3×10^7	10^8
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	0.20	15	15	15	15	15	15	15	15	15
ii)	0.30	15	15	15	15	15	15	15	14	13
iii)	0.40	15	15	10	7.2	5.2	4.1	3.5	3.1	2.7
iv)	0.50	11	7.7	4.9	3.3	2.2	1.6	1.3	1.1	0.9
v)	0.60	5.6	4.0	2.5	1.6	1.0	0.7	0.6	0.5	0.4
vi)	0.65	4.2	3.0	1.9	1.2	0.8	0.6	0.4	0.3	0.3

Table 5 Minimum Value of $10^4 R_a/D$ (where One is Required)

(*Clause* 10.1)

Sl No.	β	$R_e D$			
		$\leq 3 \times 10^6$	10^7	3×10^7	10^8
(1)	(2)	(3)	(4)	(5)	(6)
i)	≤ 0.50	0.0	0.0	0.0	0.0
ii)	0.60	0.0	0.0	0.003	0.004
iii)	≥ 0.65	0.0	0.013	0.016	0.012

The roughness requirements relate to the orifice fitting and the upstream pipe work. The downstream roughness is not as critical.

For example, the requirements of this section are satisfied in either of the following cases:

1 μm $\leq R_a \leq$ 6 μm, $D \geq$ 150 mm, β : $\leq$ 0.6 and $Re_D \leq 5 \times 10^7$; and

1 μm $\leq R_a \leq$ 6 μm, $D \geq$ 150 mm, β : $\leq$ 0.6 and $Re_D \leq 5 \times 10^7$.

where D is less than 150 mm, it is necessary to calculate the maximum and minimum values of R_a by using Tables 6 and 7.

10.2 Coefficients

10.2.1 *Discharge Coefficient, C*

The discharge coefficient, C, is given by the Reader-Harris/Gallagher (1998) equation:

$$C = 0.596\,1 + 0.026\,1\beta^2 - 0.216\beta^8$$

$$+0.000\,521\left(\frac{10^6\beta}{Re_D}\right)^{0.7}$$

$$+(0.018\,8 + 0.006\,3A)\beta^{3.5}\left(\frac{10^6}{Re_D}\right)^{0.3}$$

$$+(0.043 + 0.080e^{-10L_1} - 0.123e^{-7L_1})$$

$$(1 - 0.11A)\frac{\beta^4}{1-\beta^4} - 0.031(M_2' - 0.8M_2'^{1.1})\beta^{1.13}$$

where $D < 71$, 12 mm, the following term shall be added to Equation:

$$+0.011(0.75 - \beta)\left(2, B - \frac{D}{25.4}\right)$$

In these equations

$B\,(=d/D)$ — diameter ratio, with the diameters d and D expressed in millimetres;

Re_D — Reynolds number calculated with respect to D;

$L_1(=l_1/D)$ — quotient of the distance of the upstream tapping from the upstream face of the plate and the pipe diameter; and

$L_2'(=l_2'/D)$ — quotient of the distance of the downstream tapping from the downstream face of the plate and the pipe diameter (L_2' denotes the reference of the downstream spacing from the downstream face, while L_2 would denote the reference of the downstream spacing from the upstream face).

$$M_2' = \frac{2L_2'}{1-\beta}$$

$$A = \left(\frac{19\,000\,\beta}{Re_D}\right)^{0.8}$$

The values of L_1 and L_2' to be used in this equation, when the spacings are in accordance with the requirements of **5.2.2.2**, **5.2.2.3** or **5.2.3** are as follows:

— for corner tappings:

$L_1 = L_2' = 0$

— for D and $D/2$ tappings:

$L_1 = 1$

$L'_2 = 0.47$

— for flange tappings:

$$L_1 = L'_2 = \frac{25{,}4}{D}$$

where D is expressed in millimetres.

The Reader-Harris/Gallagher (1998) equation, is only valid for tapping arrangements. In particular, it is not permitted to enter into the pairs of values L_1 and L_2 which do not match one of the three standardized tapping arrangements.

The uncertainties are only valid when the measurement meets all the limits of use and the general installation requirements specified in **6** and in ISO 5167-1.

Values of C as a function of β, Re_D and D. These values are not intended for precise interpolation. Extrapolation is not permitted.

10.2.2 *Expansibility (Expansion) Factor*

For the three types of tapping arrangement, the empirical formula [ε] for computing the expansibility (expansion) factor, ε, is as follows:

$$\varepsilon = 1-\left(0.351+0.256\beta^4+0.93\beta^8\right)\left[1-\left(\frac{p_2}{p_1}\right)^{1/k}\right]$$

Equation is applicable only within the range of the limits of use.

Test results for the determination of ε are only known for air, steam and natural gas. However, there is known objection for other gases and vapours of which the isentropic exponent is known.

Nonetheless, Equation is applicable only if $p_2/p_1 \geq 0.75$.

Values of the expansibility (expansion) factor as a function of the isentropic exponent, the pressure ratio and the diameter ratio are given for convenience in Table 19. These values are not intended for precise interpolation. Extrapolation is not permitted.

10.3 Uncertainties

10.3.1 *Uncertainty of Discharge Coefficient, C*

For all three types of tappings, when β D, Re_D and R_a/D are assumed to be known without error, the relative uncertainty of the value of C is equal to:

a) $(0.7-\beta)$ percent for $0.1 \leq \beta < 0.2$;
b) 0.5 percent for $0.2 \leq \beta \leq 0.6$; and
c) $1.667\,\beta - 0.5$ percent for $0.6 < \beta \leq -0.75$.

If $\beta > 0.5$ and $Re_D < 10\,000$, the following relative uncertainty shall be added arithmetically to the above values.

10.3.2 *Uncertainty of Expansibility (Expansion) Factor, ε*

When β, $\Delta p/p_1$ and k are assumed to be known without error, the relative uncertainty of the value of ε is equal to:

$$3.5\,\frac{\Delta p}{kp_1}\text{ percent}$$

10.4 Pressure Loss, Δω

10.4.1 The pressure loss, Δω, for the orifice plates described in this part of ISO 5167-1 is approximately related to the differential pressure Δ*p* by:

$$\Delta\omega = \frac{\sqrt{1-\beta^4(1-C^2)}-C\beta^2}{\sqrt{1-\beta^4(1-C^2)}+C\beta^2}\Delta p$$

This pressure loss is the difference in static pressure between the pressure measured at the wall on the upstream side of the orifice plate, at a section where the influence of the approach impact pressure adjacent to the plate is still negligible (approximately D upstream of the orifice plate), and that measured on the downstream side of the orifice plate, where the static pressure recovery by expansion of the jet may be considered as just completed (approximately $6D$ downstream of the orifice plate). Figure 7 shows the pressure profile through an orifice metering system.

10.4.2 Another approximate value of Δω/Δ*p* is

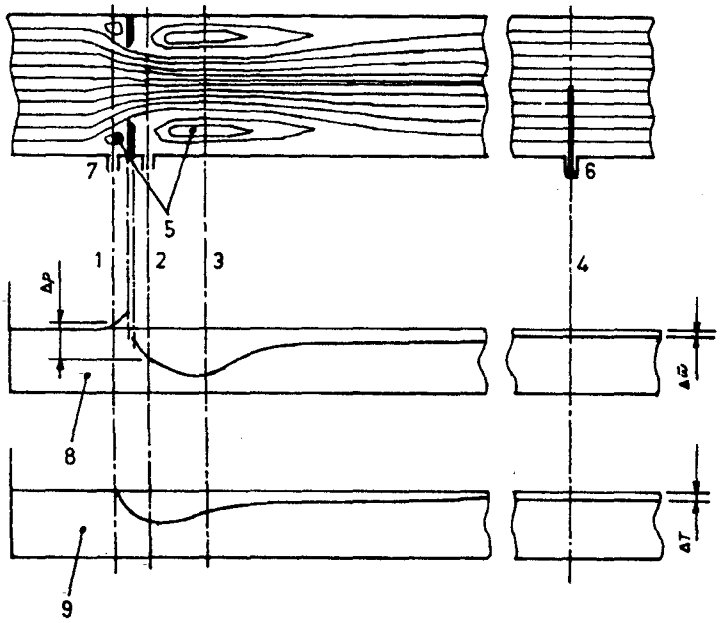
$$\frac{\Delta\omega}{\Delta p} = 1-\beta^{1.9}$$

10.4.3 The pressure loss coefficient, K, for the orifice plate is

$$K = \left(\frac{\sqrt{1-\beta^4(1-C^2)}}{C\beta^2}-1\right)^2$$

where K is defined by the following equation:

$$K = \frac{\Delta\omega}{\frac{1}{2}p_1V^2}$$



KEY

1 — plane of upstream pressure tappings
2 — plane of downstream pressure tappings
3 — plane of "vena contracta" (highest velocities)
4 — plane of temperature probe
5 — secondary flow regions
6 — thermometer pocket or well
7 — pressure tappings
8 — pressure distribution on the wall
9 — mean temperature distribution

FIG. 7 APROXIMATE PROFILES OF FLOW, PRESSURE AND TEMPERATURE IN AN ORIFICE METERING SYSTEM

11 INSTALLATION REQUIREMENTS

11.1 General

General installation requirements for pressure differential devices are given in this standard and shall be followed in conjunction with the additional specific requirements for orifice plates. The general requirements for flow conditions at the primary device are also given in this standard. The requirements for use of a flow conditioner are also mentioned. A flow conditioner will permit the use of a shorter upstream pipe length; moreover, a flow conditioner shall be installed upstream of the orifice plate where sufficient straight length to achieve the desired level of uncertainty is not available. Downstream of a header the use of a flow conditioner is strongly recommended.

11.2 Minimum Upstream and Downstream Straight Lengths for Installation Between Various Fittings and the Orifice Plate

11.2.1 The minimum straight lengths of pipe required upstream and downstream of the orifice plate for the specified fittings in the installation without flow conditioners are given in Table 6.

11.2.2 When a flow conditioner is not used, the lengths specified in Table 6 shall be regarded as the minimum values. For research and calibration work in particular, it is recommended that the upstream values specified in Table 6 be increased by at least a factor of 2 to minimize the measurement uncertainty.

11.2.3 When the straight lengths used are equal to or longer than the values specified in columns A of Table 6 for 'zero additional uncertainty', it is not necessary to increase the uncertainty in discharge coefficient to take account of the effect of the particular installation.

11.2.4 When the upstream or downstream straight length is shorter than the value corresponding to 'zero additional uncertainty' shown in columns A and either equal to or greater than the 0.5 percent additional uncertainty value shown in columns B of Table 6 for a given fitting, an additional uncertainty of 0.5 percent shall be added arithmetically to the uncertainty in the discharge coefficient.

11.2.5 This part of the standard cannot be used to predict the value of any additional uncertainty when either:

a) straight lengths shorter than the 0.5 percent additional uncertainty values specified in columns B of Table 6 are used; or

b) both the upstream and downstream straight lengths are shorter than the 'zero additional uncertainty' values specified in columns A of Table 6.

11.2.6 The value shown in Table 6 shall be set fully open during the flow measurement process. It is recommended that control of the flow rate be achieved by valves located downstream of the orifice plate. Isolating valves located upstream of the orifice plate shall be set fully open, and these valves shall be full bore. The valve shall be fitted

Table 6 Required Straight Length Between Orifice Plates and Fittings Without Flow Conditioners

(*Clauses* 11.2.1, 11.2.2, 11.2.3, 11.2.4, 11.2.5, 11.2.6, 11.2.7 *and* 11.2.8)

Values expressed as multiples of internal diameter, D

Diameter ratio β	Upstream (inlet) side of orifice plate																								Downstream (outlet) side of the orifice plate	
	Single 90° bend Two 90° bends in any plane $(S > 30D)$[a]		Two 90° bends in the same plane: S-configuration $(30D \geqslant S > 10D)$[a]		Two 90° bends in the same plane: S-configuration $(10D \geqslant S)$[a]		Two 90° bends in perpendicular planes $(30D \geqslant S \geqslant 5D)$[a]		Two 90° bends in perpendicular planes $(5D > S)$[a, b]		Single 90° tee with or without an extension Mitre 90° bend		Single 45° bend Two 45° bends in the same plane: S-configuration $(S \geqslant 2D)$[a]		Concentric reducer $2D$ to D over a length of $1,5D$ to $3D$		Concentric expander $0,5D$ to D over a length of D to $2D$		Full bore ball valve or gate valve fully open		Abrupt symmetrical reduction		Thermometer pocket or well[c] of diameter $\leqslant 0,03D$[d]		Fittings (*columns* 2 to 11) and the densitometer pocket	
1	2		3		4		5		6		7		8		9		10		11		12		13		14	
—	A[e]	B[f]	A[e]	B[f]	A[e]	B[f]	A[e]	B[f]	A[e]	B[f]	A[e]	B[f]	A[e]	B[f]	A[e]	B[f]	A[e]	B[f]	A[e]	B[f]	A[e]	B[f]	A[e]	B[f]	A[e]	B[f]
$\leqslant 0,20$	6	3	10	[g]	10	[g]	19	18	34	17	3	[g]	7	[g]	5	[g]	6	[g]	12	6	30	15	5	3	4	2
0,40	16	3	10	[g]	10	[g]	44	18	50	25	9	3	30	9	5	[g]	12	8	12	6	30	15	5	3	6	3
0,50	22	9	18	10	22	10	44	18	75	34	19	9	30	18	8	5	20	9	12	6	30	15	5	3	6	3
0,60	42	13	30	18	42	18	44	18	65[h]	25	29	18	30	18	9	5	26	11	14	7	30	15	5	3	7	3,5
0,67	44	20	44	18	44	20	44	20	60	18	36	18	44	18	12	6	28	14	18	9	30	15	5	3	7	3,5
0,75	44	20	44	18	44	22	44	20	75	18	44	18	44	18	13	8	36	18	24	12	30	15	5	3	8	4

NOTE 1 The minimum straight lengths required are the lengths between various fittings located upstream or downstream of the orifice plate and the orifice plate itself. Straight lengths shall be measured from the downstream end of the curved portion of the nearest (or only) bend or of the tee or the downstream end of the curved or conical portion of the reducer or the expander.

NOTE 2 Most of the bends on which the lengths in this table are based had a radius of curvature equal to $1,5D$.

[a] *S is the separation between the two bends measured from the downstream end of the curved portion of the upstream bend to the upstream end of the curved portion of the downstream bend.*

[b] This is not a good upstream installation; a flow conditioner should be used where possible.

[c] The installation of thermometer pockets or wells will not alter the required minimum upstream straight lengths for the other fittings.

[d] A thermometer pocket or well of diameter between $0,03D$ and $0,13D$ may be installed provided that the values in Columns A and B are increased to 20 and 10 respectively. Such an installation is not, however, recommended.

[e] Column A for each fitting gives lengths corresponding to "zero additional uncertainty" values (*see* **11.2.3**).

[f] Column B for each fitting gives lengths corresponding to "0,5 % additional uncertainty" values (*see* **11.2.4**).

[g] The straight length in Column A gives zero additional uncertainty; data are not available for shorter straight lengths which could be used to give the required straight lengths for Column B.

[h] $95D$ is required for $Re_D > 2 \times 10^6$ if $S < 2D$.

with stops for alignment of the ball in the open position. The valve shown in Table 6 is one which is of the same nominal diameter as the upstream pipe.

11.2.7 In the metering system, upstream valves which are match bored to the adjacent pipe work and are designed in such a manner that can be regarded as part of the metering pipe work length and do not need to have added lengths as in Table 6 provided that when flow is being measured they are fully open.

11.2.8 The values given in Table 6 were determined experimentally with a very long straight length of pipe upstream of the fitting in question so that the flow immediately upstream of the fitting was considered as fully developed and swirl-free. Since in practice such conditions are difficult to achieve, the following information may be used as a guide for normal installation practice.

a) Several fittings of the type covered by Table 6, treating the combinations of 90° bends already covered by these tables as a single fitting, are placed in series upstream of the orifice plate (*see* Fig. 8).

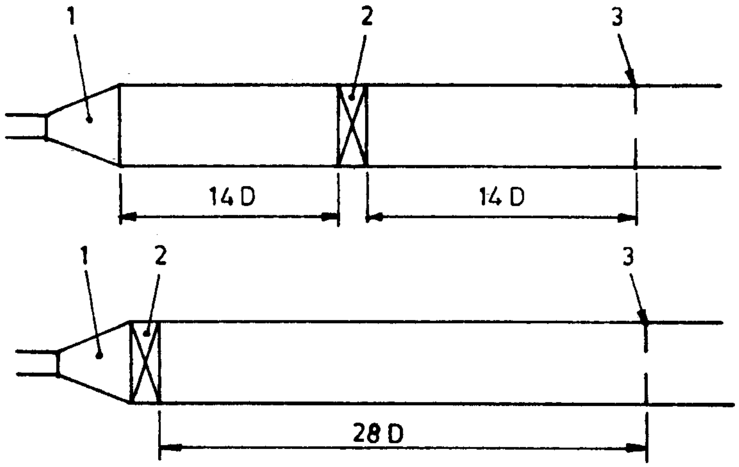
b) In addition to the rule in (a) any fitting, treating any two consecutive 90° bends as a single fitting, shall be located at a distance from the orifice plate at least as great as the distance given by the product of the pipe diameter at the orifice and the number of diameters required between that fitting and an orifice plate of the same diameter ratio in Table 6, regardless of the number of fittings between that fitting and the orifice plate. The distance between the orifice plate and the fitting shall be measured along the pipe axis. If, for any upstream fitting, the distance meets this requirement using the number of diameters in columns B but not that in columns A then a 0.5 percent additional uncertainty shall be added arithmetically to the discharge coefficient uncertainty, but this additional uncertainty shall not be added more than once under the provisions of (a) and (b).

c) It is strongly recommended that a flow conditioner shall be installed downstream of a metering system header (for example, one whose cross-section area is approximately equal to 1.5 times the cross-sectional area of the operating flow meter tubes) since there will always be distortion of the flow profile and a high probability of swirl.

d) When the second (or more distant) fitting from the orifice is a combination of bends, then in applying Table 6 the separation between the bends is calculated as a multiple of the diameter of the bends themselves.

11.2.9 By way of example, three cases of the application of **11.2.8** (a) and (b) are considered. In each case, 1 second fitting from the orifice plate is two bends in perpendicular planes (the separation between the bends is 10 times the diameter of the bends) and the orifice plate has diameter ratio 0.4.

If the first fitting is a full bore ball valve fully open [*see* Fig. 9 (a)], the distance between the valve and the orifice plate shall be at least $12D$ (from Table 5) and that between the two bends perpendicular planes and the valve shall be at least $22D$ [from **11.2.8** (a)]; the distance between the two bends in perpendicular planes and the orifice plate shall be at least $44D$ [from **11.2.8** (b)].



KEY

1 — expander

2 — full bore ball valve or gate valve fully open

3 — orifice plate

FIG. 8 LAYOUT INCLUDING A FULL BORE VALVE FOR $\beta = 0.6$

If the first fitting is a reducer from 2*D* to *D* over a length of 2*D* [*see* Fig. 9 (c)], the distance between the reducer and the orifice plate shall be at least 5*D* (from Table 6) and that between the two bends in perpendicular planes and the reducer shall be at least 22 x 2*D* [from **11.2.8** (a)]; the distance between the bends in perpendicular planes and the orifice plate shall be at least 44*D*. So no additional length is required because of **11.2.8** (b).

If the first fitting is an expander from 0.5*D* to *D* over a length of 2*D* [*see* Fig. 9(d)], the distance between the expander and the orifice plate shall be at least 12*D* (from Table 5) and that between the bends in perpendicular planes and the expander shall be at least 22 × 0.5*D* [from **6.2.8** (a)]; the distance between the two bends in perpendicular planes and the orifice plate shall be at least 44*D* [from **11.2.8** (b)]. So an additional total length of 19*D* is required which may be either upstream or downstream of the expanded partly upstream and partly downstream of it.

12 FLOW CONDITIONERS

12.1 General

A flow conditioner can be used to reduce upstream straight lengths either through meeting the compliance test given in this standard, in which case it can be used downstream of any upstream fitting, or through meeting the requirements of this standard, which gives additional possibilities outside compliance testing. In either case the test work shall be carried out using orifice plates.

Unpatented flow conditioners which have met the

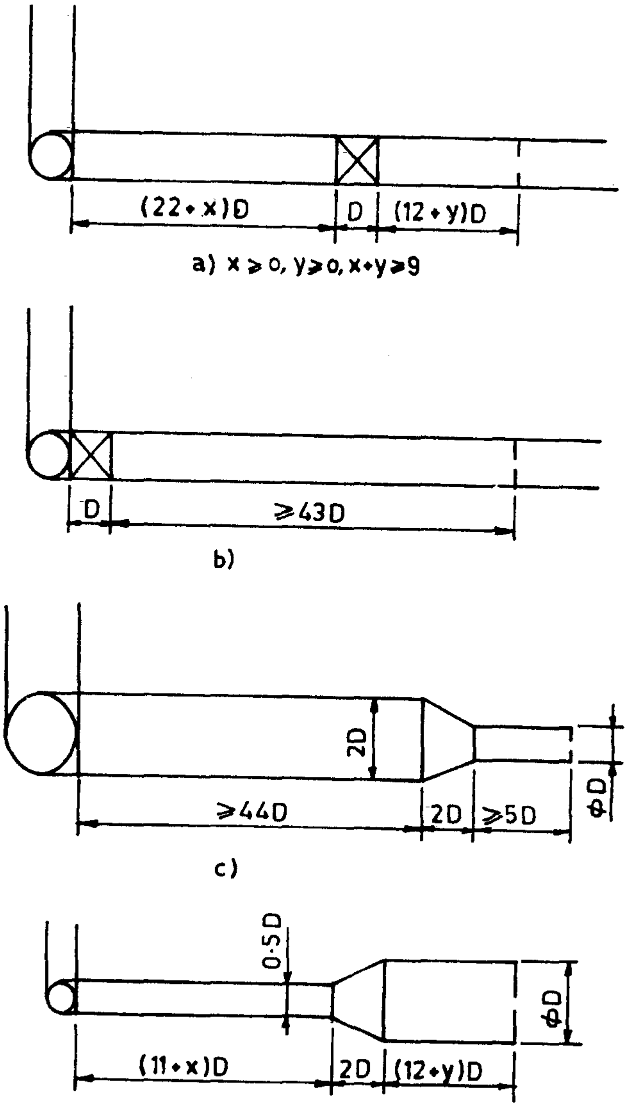


FIG. 9 EXAMPLES OF ACCEPTABLE INSTALLATION

compliance test of this standard are the 19-tube bundle flow straightener (1998) and the Zanker flow conditioner plate. Annex B describes some patented flow conditioners which have met the compliance test. Clause **12.2** and **12.6** give the situations in which the 19-tube bundle flow straightener (1998) and the Zanker flow conditioner plate can be used upstream of orifice plates. Clause **12.4** and **12.6.2** describe the situations in which the 19-tube bundle flow straightener (1998) and the Zanker flow conditioner plate can be used downstream of any fitting. Clause **12.5** describes some additional situations in which the 19-tube bundle flow straightener (1998)] may be used to reduce the required upstream length. Annex B describes some flow conditioners which can be used upstream of orifice plates and the requirements for straight lengths associated with them. It is not intended that the inclusion of the flow conditioners described there should limit the use of other flow conditioner designs which have been tested and proved to provide sufficiently small shifts in discharge coefficient.

12.2 19-Tube Bundle Flow Straightener (1998)

The 19-tube bundle flow straightener (1998) shall consist of 19 tubes arranged in a cylindrical pattern as in Fig. 10.

In order to reduce the swirl that can occur between the exterior tubes of the 19-tube bundle flow straightener (1998) and the wall of the pipe, the maximum outside diameter of the flow straightener, D_f shall satisfy

$$0.95D \leq D_f \leq D$$

The length, L, of the tubes shall be between $2D$ and $3D$, preferably as close to $2D$ as possible.

12.2.1 *Description*

12.2.2 *Design*

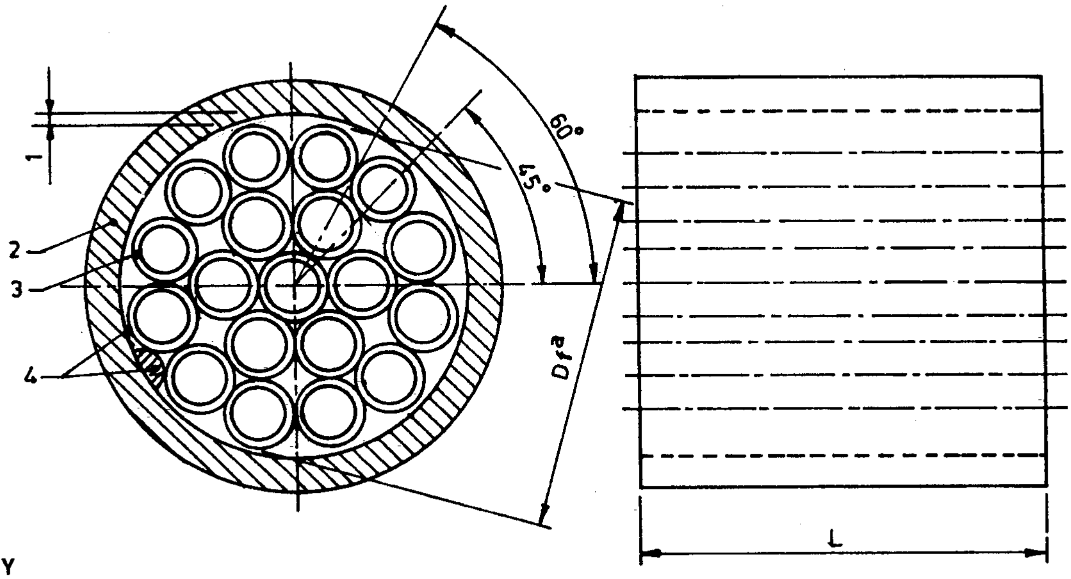
12.3 Tubing of the 19-Tube Bundle Flow Straightener (1998)

All the tubes in the tube bundle shall be of uniform smoothness, outer diameter and wall thickness. The individual tube wall thickness of the 19-tube bundle flow straightener (1998) shall be thin. All tubes shall have an internal chamfer on both ends.

The wall thickness shall be less than $0.025D$; this value is based on the wall thickness of the tubes used to collect the data on which this standard is based.

12.3.1 *Fabrication of the 19-Tube Bundle Flow Straightener (1998)*

The 19-tube bundle flow straightener (1998) shall be sturdily fabricated. Individual tubes shall be welded together at the points of contact, at least at both ends of the tube bundle. It is important to ensure that the tubes are parallel to each other and to the pipe axis since, if compliance with this



KEY

1 — minimized gap
2 — pipe wall
3 — tube wall thickness
4 — centring spacer options (typically four places)

a) D_f = flow straightener outside diameter

FIG. 10 FABRICATION OF THE 19-TUBE BUNDLE FLOW STRAIGHTENER (1998)

requirement is not met, the straightener itself may introduce swirl into the flow. Centring spacers may be provided on the outside of the assembly to assist the installer in centring the device in the pipe; these may take the form of small lugs small rods parallel to the pipe axis. After being inserted in the pipe, the tube bundle shall be securely fastened in place. Secure fastening, however, should not distort the tube bundle assembly with respect to symmetry within the pipe.

12.3.2 *Pressure Loss*

The pressure loss coefficient, K, for the 19-tube bundle flow straightener (1998) is approximately equal to 0.75, where K is given by the following equation:

$$K = \frac{\Delta P_C}{\frac{1}{2}\rho v^2}$$

where

ΔP_C = pressure loss across the 19-tube bundle flow straightener (1998);

ρ = density of the fluid in the pipe; and

v = mean axial velocity of the fluid in the pipe.

12.4 Installation Downstream of Any Fitting

12.4.1 The 19-tube bundle flow straightener (1998) shown in Fig. 10 can be used downstream of any upstream fitting with an orifice plate whose diameter ratio is 0.67 or smaller provided that it meets the manufacturing specification and is installed in accordance with specific clause.

12.4.2 The 19-tube bundle flow straightener (1998) shall be installed so that the distance between the downstream end of the 19-tube bundle flow straightener (1998) and the orifice plate is equal to $13D \pm 0.25D$.

12.5 Additional Options

12.5.1 A 19-tube bundle flow straightener (1998) may also be used to reduce the required upstream straight length in situations outside the situation as described in respective clause. The 19-tube bundle flow straightener (1998) shall be as described in specific clause.

The permitted locations for the 19-tube bundle flow straightener (1998) depend on L_f, the distance from the orifice plate to the nearest upstream fitting, measured to the downstream end of the curved portion of the nearest (or only) bend or of the tee or the downstream end of the curved or conical portion of the reducer or expander.

Table 7 provides the permitted location range and the recommended location for the 19-tube bundle flow straightener (1998) for two ranges of L_f:

a) $30D > L_f \geq 18D$, and

b) $L_f \geq 30D$.

L_f shall be greater than or equal to $18D$. The locations for the 19-tube bundle flow straightener (1998) are described in Table 7 in terms of the straight lengths between the downstream end of the 19-tube bundle flow straightener (1998) and the orifice plate.

If, for a particular upstream fitting, an orifice plate diameter ratio and a value of L_f, there is no location shown in Table 7 for a 19-tube bundle flow straightener (1998), then an installation with this fitting, β and L_f, is not recommended. In this case, an increase in L_f and/or a reduction in β is necessary.

The length required downstream of the orifice plate shall be as given in Table 6.

An example of the use of Table 7 is given in the respective clause.

12.5.2 When the straight length between orifice plate and 19-tube bundle flow straightener (1998) is in accordance with the values specified in columns A of Table 6 and the downstream straight length in accordance with columns A of Table 7 for 'zero additional uncertainty', it is not necessary to increase the uncertainty in discharge coefficient to take account of the effect of the particular installation.

12.5.3 An additional uncertainty of 0.5 percent shall be added arithmetically to the uncertainty in the discharge coefficient when either:

a) the straight length between orifice plate and 19-tube bundle flow straightener (1998) is not in accordance with the value corresponding to 'zero additional uncertainty' shown in columns A but in accordance with the value corresponding to '0.5 percent additional uncertainty' shown in columns B of Table 7; or

b) the downstream straight length is shorter than the value corresponding to 'zero additional uncertainty' shown in columns A but either equal to or greater than the '0.5 percent additional uncertainty' value shown in columns B of Table 6 for a given fitting.

12.5.4 This standard shall not be used to predict the value of any additional uncertainty when:

a) the straight length between orifice plate and 19-tube bundle flow straightener (1998) is not in accordance with the value corresponding to 0.5 percent additional uncertainty shown in columns B of Table 7; or

Table 7 Permitted Range of Straight Lengths Between an Orifice Plate and a 19-Tube Bundle Flow Straightener (1998) Downstream of Fittings Located at a Distance, L_f, from the Orifice Plate

(*Clauses* 12.5.1, 12.5.2, 12.5.3, 12.5.4 *and* 12.5.5)

Values expressed as multiples of internal diameter, D

Diameter ratio β	**Single 90° bend** [b]				**Two 90° bends** [b] **in perpendicular planes** ($2D \geqslant S$) [a]				**Single 90° tee**				**Any fitting**			
	$30 > L_f \geqslant 18$		$L_f \geqslant 30$		$30 > L_f \geqslant 18$		$L_f \geqslant 30$		$30 > L_f \geqslant 18$		$L_f \geqslant 30$		$30 > L_f \geqslant 18$		$L_f \geqslant 30$	
1	2		3		4		5		6		7		8		9	
—	A [c]	B [d]	A [c]	B [d]	A [c]	B [d]	A [c]	B [d]	A [c]	B [d]	A [c]	B [d]	A [c]	B [d]	A [c]	B [d]
$\leqslant 0{,}2$	5 to 14,5	1 to n [e]	5 to 25	1 to n [e]	5 to 14,5	1 to n [e]	5 to 25	1 to n [e]	5 to 14,5	1 to n [e]	1 to 25	1 to n [e]	5 to 11	1 to n [e]	5 to 13	1 to n [e]
0,4	5 to 14,5	1 to n [e]	5 to 25	1 to n [e]	5 to 14,5	1 to n [e]	5 to 25	1 to n [e]	5 to 14,5	1 to n [e]	1 to 25	1 to n [e]	5 to 11	1 to n [e]	5 to 13	1 to n [e]
0,5	11,5 to 14,5	3 to n [e]	11,5 to 25	3 to n [e]	9,5 to 14,5	1 to n [e]	9 to 25	1 to n [e]	11 to 13	1 to n [e]	9 to 23	1 to n [e]	[f] [g]	3 to n [e]	11,5 to 14,5	3 to n [e]
0,6	12 to 13	5 to n [e]	12 to 25	5 to n [e]	13,5 to 14,5	6 to n [e]	9 to 25	1 to n [e]	[f] [h]	7 to n [e]	11 to 16	1 to n [e]	[f]	7 to n [e]	12 to 16	6 to n [e]
0,67	13	7 to n [e]	13 to 16,5	7 to n [e]	13 to 14,5	7 to n [e]	10 to 16	5 to n [e]	[f]	8 to n [e]	11 to 13	6 to n [e]	[f]	8 to 10	13	7 to n-1,5 [e]
0,75	14	8 to n [e]	14 to 16,5	8 to n [e]	[f]	9,5 to n [e]	12 to 12,5	8 to n [e]	[f]	9 to n [e]	12 to 14	7 to n [e]	[f]	9,5	[f]	8 to 22
Recommended	13 for $\beta \leqslant 0{,}67$	13 for $\beta \leqslant 0{,}75$	14 to 16,5 for $\beta \leqslant 0{,}75$	14 to 16,5 for $\beta \leqslant 0{,}75$	13,5 to 14,5 for $\beta \leqslant 0{,}67$	13,5 to 14,5 for $\beta \leqslant 0{,}75$	12 to 12,5 for $\beta \leqslant 0{,}75$	12 to 12,5 for $\beta \leqslant 0{,}75$	13 for $\beta \leqslant 0{,}54$	13 for $\beta \leqslant 0{,}75$	12 to 13 for $\beta \leqslant 0{,}75$	12 to 13 for $\beta \leqslant 0{,}75$	9,5 for $\beta \leqslant 0{,}46$	9,5 for $\beta \leqslant 0{,}75$	13 for $\beta \leqslant 0{,}67$	13 for $\beta \leqslant 0{,}75$

NOTE The straight lengths given in the table are the permitted lengths between the downstream end of a 19-tube bundle flow straightener (1998) (as described in **12.5.3**) and the orifice plate given that a particular fitting is installed upstream of the 19-tube bundle flow straightener (1998) at a distance L_f from the orifice plate. The distance L_f from the orifice plate is measured to the downstream end of the curved portion of the nearest (or only) bend or of the tee or the downstream end of the curved or conical portion of the reducer or expander. The recommended values give tube bundle locations that are applicable over a specified range of β.

[a] S is the separation between the two bends measured from the downstream end of the curved portion of the upstream bend to the upstream end of the curved portion of the downstream bend.

[b] Bends should have a radius of curvature equal to $1{,}5D$.

[c] Column A for each fitting gives lengths corresponding to "zero additional uncertainty" values (*see* **12.5.2**).

[d] Column B for each fitting gives lengths corresponding to "0,5 % additional uncertainty" values (*see* **12.5.3**).

[e] n is the number of diameters such that the upstream end of the 19-tube bundle flow straightener (1998) is situated $1D$ from the downstream end of the curved or conical portion of the nearest fitting. It is desirable that the length between the upstream end of the 19-tube bundle flow straightener (1998) and the downstream end of the curved or conical portion of the nearest fitting should be at least $2{,}5D$, except where this would not give an acceptable value for the distance between the orifice plate and the downstream end of the 19-tube bundle flow straightener (1998).

[f] It is not possible to find an acceptable location for a 19-tube bundle flow straightener (1998) downstream of the particular fitting for all values of L_f to which the column applies.

[g] If $\beta = 0{,}46$ a value of 9,5 is possible.

[h] If $\beta = 0{,}54$ a value of 13 is possible.

b) the downstream straight length is shorter than the 0.5 percent additional uncertainty value specified in columns B of Table 6; or

c) both the straight length between orifice plate and 19-tube bundle flow straightener (1998) is not in accordance with the value corresponding to zero additional uncertainty shown in columns A of Table 7 and the downstream straight length is shorter than the 'zero additional uncertainty' value specified in columns A of Table 6.

12.5.5 The values given in Table 7 have been determined experimentally with a very long straight length mounted upstream of the fitting in question so that the flow immediately upstream of the fitting was considered as fully developed and swirl-free. Since in practice such conditions are difficult to achieve, there shall be al least 15*D* of straight pipe between the fitting listed in Table 7 and the nearest fitting beyond that one, unless the columns relating to any fitting are used (*see* example).

Example:

If it is necessary to install a single bend upstream of an orifice plate of diameter ratio 0.6, there are two options using a 19-tube bundle flow straightener (1998) which will reduce the upstream length in comparison with the 42*D* required (*see* Table 6) if no flow conditioner is used. Either an installation as in **12.4** is permissible [*see* Fig. 9 (a)] which has the advantage that any fitting can be placed at any distance upstream of the single bend or an installation as in Table 7 is permissible [*see* Fig. 11 (b)] which gives a shorter straight length required downstream of the bend but a straight length required upstream of the bend. If the upstream straight length from the orifice plate to the bend is greater than or equal to 30*D*, Table 7 can also be used to provide wider range of tube bundle locations but since these locations will rarely be required in designing installations these options are not shown in Fig. 11.

12.6 Zanker Flow Conditioner Plate

12.6.1 *Description*

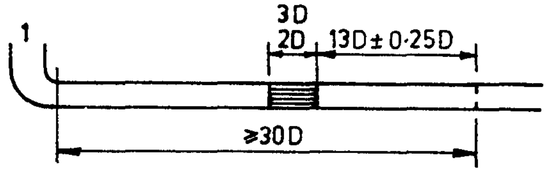
The Zanker flow conditioner plate described here is a development of the Zanker conditioner. The Zanker flow conditioner plate has the same distribution of holes in a plate but does not have the egg-box honeycomb attached to the plate; instead the plate thickness has been increased to *D*/8. It is not patented.

The Zanker flow conditioner plate shown in Fig. 12 met the compliance test requirements. A Zanker flow conditioner plate which meets the manufacturing and installations as per this standard.

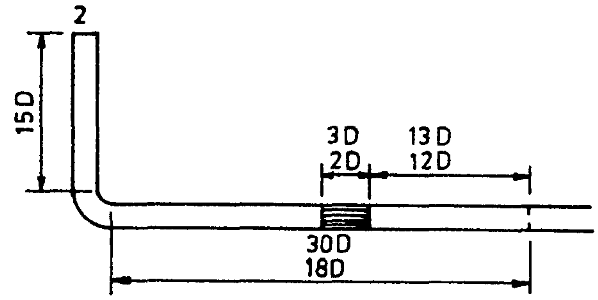
12.6.2 *Design*

The Zanker flow conditioner plate is illustrated in Fig. 12 and consists of 32 bored holes arranged in a symmetrical circular pattern. The dimensions of the holes are a function of the pipe inside diameter *D* and shall be as follows:

a) a ring of 4 central holes of diameter $0.141D \pm 0.001D$ on a pitch circle diameter of $0.25D \pm 0.002\,5D$;



a) Installation Using (**12.4**)



b) Installation Using (Table 7)

KEY

1 — position of any fitting placed at any distance upstream of the single bend

2 — position of previous fitting placed before straight length upstream of the single bend

FIG. 11 EXAMPLE OF INSTALLATIONS WITH A 19-TUBE BUNDLE FLOW STRAIGHTENER (1998) DOWNSTREAM OF A SINGLE BEND

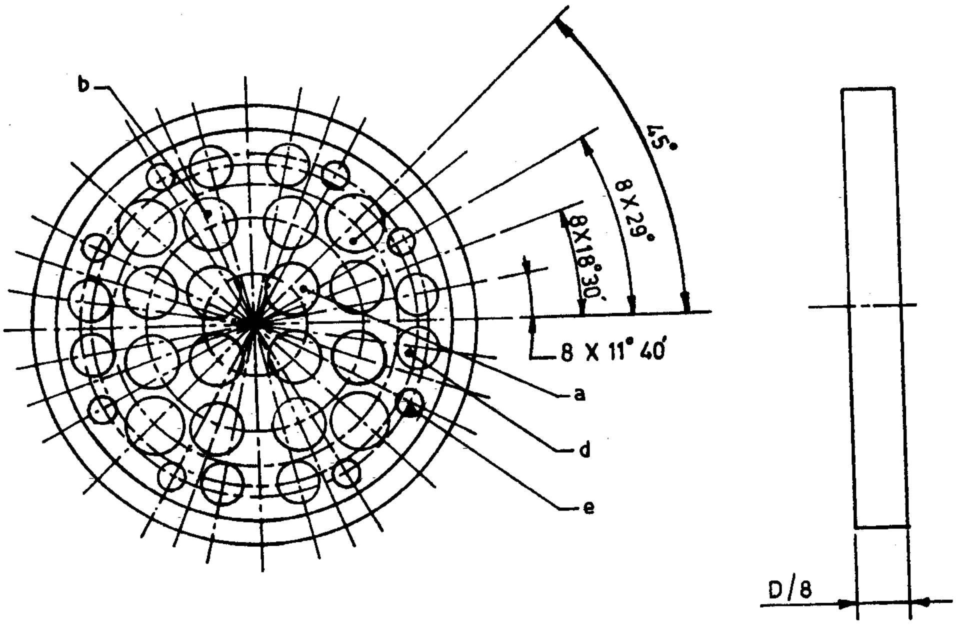


FIG. 12 DRAWING OF THE ZANKER FLOW CONDITIONER PLATE

b) a ring of 8 holes of diameter $0.139D \pm 0.001D$ on a pitch circle diameter of $0.56D \pm 0.005\,6D$;

c) a ring of 4 holes of diameter $0.136\,5D \pm 0.001D$ on a pitch circle diameter of $0.75D \pm 0.007\,5D$;

d) a ring of 8 holes of diameter $0.110D \pm 0.001D$ on a pitch circle diameter of $0.85D \pm 0.008\,5D$; and

e) a ring of 8 holes of diameter $0.077D \pm 0.001D$ on a pitch circle diameter of $0.90D \pm 0.009D$.

The tolerance on the diameter of each hole is: ± 0.1 mm for $D < 100$ mm.

The perforated plate thickness, t_c' is such that $0.12D \leq t_c \leq 0.15D$. The flange thickness depends on the application; the outer diameter and flange face surfaces depend on the flange type and application.

The pressure loss coefficient, K, for the Zanker flow conditioner plate is approximately equal to 3, where K is given by the following equation:

$$K = \frac{\Delta P_C}{\frac{1}{2}\rho v^2}$$

where

ΔP_C = pressure loss across the Zanker flow conditioner plate;

ρ = density of the fluid in the pipe; and

v = mean axial velocity of the fluid in the pipe.

12.6.3 *Installation*

L_f, the distance between the orifice plate and the nearest upstream fitting, shall be at least equal to $17D$. The Zanker flow conditioner plate shall be installed so that L_s, the distance between the downstream face of the conditioner plate and the orifice plate, is such that:

$$7.5D \leq L_s \leq L_f - 8.5D$$

The Zanker flow conditioner plate can be used for $\beta \leq 0.67$.

The distance to a bend (or bend combination) or a tee is measured to the downstream end of the curved portion of the nearest (or only) bend or of the tee. The distance to a reducer or expander is measured to the downstream end of the curved or conical portion of the reducer or the expander.

The locations in this subclause are acceptable downstream of any fitting. A wider range of locations for the Zanker flow conditioner plate is permissible if the range of upstream fittings is restricted or the overall length between the upstream fitting and the orifice plate is increased or the diameter ratio of the orifice plate is reduced. These locations are not described here.

12.7 Circularity and Cylindricality of the Pipe

12.7.1 The $2D$ length of the upstream pipe section adjacent to the orifice plate (or to the carrier ring if there is one) shall be manufactured with special care and shall meet the requirement that no diameter in any plane in this length shall differ by more than 0.3 percent from the mean value of *D* obtained from the measurements. The value for the pipe diameter *D* shall be the mean of the internal diameters over a length of 0.5*D* upstream of the upstream pressure tapping. The internal mean diameter shall be the arithmetic mean of measurements of at least twelve diameters, namely, four diameters positioned at approximately equal angles, to each other, distributed in each of at least three cross-sections evenly distributed over a length of 0.5*D*, two of the sections being at distance 0*D* and 0.5*D* from the upstream tapping and one being in the plane of the weld in the case of a weld-neck construction. If there is a carrier ring (*see* Fig. 6), this value of 0.5*D* shall be measured from the upstream edge of the carrier ring.

Beyond 2*D* from the orifice plate, the upstream pipe run between the orifice plate and the first upstream fitting or disturbance may be made up of one or more sections of pipe.

12.7.2 Between 2*D* and 10*D* from the orifice plate, no additional uncertainty in the discharge coefficient is involved provided that the diameter step (the difference between the diameters) between any two sections does not exceed 0.3 percent of the mean value of *D* obtained from the measurements. Moreover, the actual step caused by misalignment and/or change in diameter shall not exceed 0.3 percent of *D* at any point of the internal circumference of the pipe. Therefore, mating flanges would require the bores to be matched and the flanges aligned on installation. Dowels or self-centring gaskets may be used.

12.7.3 Beyond 10*D* from the orifice plate, no additional uncertainty in the discharge coefficient is involved provided that the diameter step (the difference between the diameters) between any two sections does not exceed 2 percent of the mean value of *D* obtained from the measurements. Moreover, the actual step caused by misalignment and/or change in diameter shall not exceed 2 percent of *D* at any point of the internal circumference of the pipe. If the pipe diameter upstream of the step is greater than that downstream of it, the permitted diameter and actual steps are increased from 2 percent to 6 percent of *D*. On each side of the step, the pipe shall have a diameter between 0.98*D* and 1.06*D*. Beyond 10*D* from the orifice plate, the use of gaskets between sections will not violate this requirement provided that in use they are no thicker than 3.2 mm and they do not protrude into the flow.

12.7.4 At a location which is both beyond 10*D* from the orifice plate and beyond the first location where an expander could be fitted in accordance with Column 10A of Table 6, no additional uncertainty in the discharge coefficient is involved provided that the diameter step (the difference between the diameters) between any two sections does not exceed 6 percent of the mean value of *D* obtained from the measurements specified in **6.4.2**. Moreover, the actual step caused by misalignment and/or change in diameter shall not exceed 6 percent of *D* at any point of the internal circumference of the pipe. On each side of the step, the pipe shall have a diameter between 0.94*D* and 1.06*D*. The first location where an expander could be fitted in accordance with Column 10A of Table 6 depends on the diameter ratio of the orifice plate, for example, it is 26*D* from the orifice plate if $\beta = 0.6$.

12.7.5 An additional uncertainty of 0.2 percent shall be added arithmetically to the uncertainty for the discharge coefficient if the diameter step (MJ) between any two sections exceeds the limits given in **12.7** but complies with the following relationship:

$$\frac{\Delta D}{D} < 0.002\left(\frac{\frac{s}{D}+0.4}{0.1+2.3\beta^4}\right)$$

and

$$\frac{\Delta D}{D} < 0.05$$

where

s is the distance of the step from the upstream pressure tapping or, if a carrier ring is used, from the upstream edge of the recess formed by the carrier ring.

If a step is greater than any one of the limits given in the inequalities above or if there is more than one step outside the limits in the specified clause, the installation is not in accordance with this standard.

No diameter of the downstream straight length, considered along a length of at least 2*D* from the upstream face of the orifice plate, shall differ from the mean diameter of the upstream straight length by more than 3 percent. This can be judged by checking a single diameter of the downstream straight length. Mating flanges would require the bores to be matched and the flanges aligned on installation. Dowels or self-centring gaskets could be used.

12.8 Location of Orifice Plate and Carrier Rings

12.8.1 The orifice plate shall be placed in the pipe in such a way that the fluid flows from the upstream face towards the downstream face.

12.8.2 The orifice plate shall be perpendicular to the centreline of the pipe to within 1°.

12.8.3 The orifice plate shall be centred in the pipe. The distance between the centreline of the orifice and the centrelines of the pipe on the upstream and downstream sides shall be measured, and for each pressure tapping the components of the distance between the centreline of the orifice and the centreline of the pipe in which it is located in the directions parallel to and perpendicular to the axis of the pressure tapping shall be determined.

The component in the direction parallel to the pressure tapping e_{cl}, shall for each pressure tapping be such that

$$e_{cl} \leq \frac{0.002\,5D}{0.1 + 2.3\beta^4}$$

e_{cn}, the component in the direction perpendicular to the pressure tapping, shall for each pressure tapping be such that

$$e_{cn} \leq \frac{0.005D}{0.1 + 2.3\beta^4}$$

If, for one or more pressure tappings,

$$\frac{0.002\,5D}{0.1 + 2.3\beta^4} < e_{cl} \leq \frac{0.005D}{0.1 + 2.3\beta^4}$$

An additional uncertainty of 0.3 percent shall be added arithmetically to the uncertainty on the discharge coefficient *C*. The additional uncertainty shall only be added once even if the above inequality holds for several pressure tappings.

In the case where, for any pressure tapping,

$$\text{either } e_{cl} \text{ or } e_{cn} > \frac{0.005D}{0.1 + 2.3\beta^4}$$

This standard gives no information for forecasting any additional uncertainty due to lack of concentricity.

When carrier rings are used, they shall be centred such that they do not protrude into the pipe at any point.

12.9 Method of Fixing and Gaskets

The method of fixing and tightening shall be such that once the orifice plate has been installed in the proper position, it remains so.

It is necessary, when holding the orifice plate between flanges, to allow for its free thermal expansion and to avoid buckling and distortion.

Gaskets or sealing rings shall be made and inserted in such a way that they do not protrude at any point inside the pipe or across the pressure tappings or slots when corner tappings are used. They shall be as thin as possible, with due consideration taken in maintaining the relationship as defined in **9**.

If gaskets are used between the orifice plate and the annular chamber rings, they shall not protrude inside the annular chamber.

13 MARKING

13.1 The meter shall be marked with at least the following information:

a) Manufacturer's name or trade-mark;
b) Serial number;
c) Maximum flow rate, q_{Max} in actual volume units;
d) Maximum allowable operating pressure; and
e) Minimum flow rate, q_{Max} at 1.2 kg/m^3 fluid density.

13.2 BIS Certification Marking

The product may also be marked with the Standard Mark.

13.2.1 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 1986 and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

ANNEX A

(*Foreword*)

A-1 TABLES OF DISCHARGE COEFFICIENTS AND EXPANSIBILITY (EXPANSION) FACTORS (*see* TABLES 8 TO 19)

Table 8 Orifice Plate with Corner Tappings — Discharge Coefficient, *C*, for $D \geq 71.12$ mm

Diameter ratio	Discharge coefficient, C, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 6	0,599 0	0,598 0	0,597 6	0,597 2	0,597 0	0,596 9	0,596 6	0,596 5	0,596 4	0,596 4	0,596 4
0,12	0,601 4	0,599 5	0,598 3	0,597 9	0,597 5	0,597 3	0,597 1	0,596 8	0,596 6	0,596 5	0,596 5	0,596 5
0,14	0,602 1	0,600 0	0,598 7	0,598 2	0,597 7	0,597 5	0,597 3	0,596 9	0,596 8	0,596 6	0,596 6	0,596 6
0,16	0,602 8	0,600 5	0,599 1	0,598 5	0,598 0	0,597 8	0,597 6	0,597 1	0,596 9	0,596 8	0,596 8	0,596 8
0,18	0,603 6	0,601 1	0,599 5	0,598 9	0,598 3	0,598 1	0,597 8	0,597 4	0,597 1	0,597 0	0,597 0	0,596 9
0,20	0,604 5	0,601 7	0,600 0	0,599 3	0,598 7	0,598 4	0,598 1	0,597 6	0,597 4	0,597 2	0,597 2	0,597 1
0,22	0,605 3	0,602 3	0,600 5	0,599 8	0,599 1	0,598 7	0,598 5	0,597 9	0,597 6	0,597 4	0,597 4	0,597 4
0,24	0,606 2	0,603 0	0,601 0	0,600 2	0,599 5	0,599 1	0,598 8	0,598 2	0,597 9	0,597 7	0,597 6	0,597 6
0,26	0,607 2	0,603 8	0,601 6	0,600 7	0,599 9	0,599 6	0,599 2	0,598 6	0,598 2	0,598 0	0,597 9	0,597 9
0,28	0,608 3	0,604 6	0,602 2	0,601 3	0,600 4	0,600 0	0,599 7	0,599 0	0,598 6	0,598 3	0,598 2	0,598 1
0,30	0,609 5	0,605 4	0,602 9	0,601 9	0,601 0	0,600 5	0,600 1	0,599 4	0,598 9	0,598 6	0,598 5	0,598 4
0,32	0,610 7	0,606 3	0,603 6	0,602 6	0,601 6	0,601 1	0,600 6	0,599 8	0,599 3	0,599 0	0,598 8	0,598 7
0,34	0,612 0	0,607 3	0,604 4	0,603 3	0,602 2	0,601 7	0,601 2	0,600 3	0,599 8	0,599 3	0,599 2	0,599 1
0,36	0,613 5	0,608 4	0,605 3	0,604 0	0,602 9	0,602 3	0,601 8	0,600 8	0,600 2	0,599 7	0,599 6	0,599 4
0,38	0,615 1	0,609 6	0,606 2	0,604 9	0,603 6	0,603 0	0,602 4	0,601 3	0,600 7	0,600 1	0,599 9	0,599 8
0,40	0,616 8	0,610 9	0,607 2	0,605 8	0,604 4	0,603 7	0,603 1	0,601 9	0,601 2	0,600 6	0,600 3	0, 600 1
0,42	0,618 7	0,612 2	0,608 3	0,606 7	0,605 2	0,604 4	0,603 8	0,602 5	0,601 7	0,601 0	0,600 7	0,600 5
0,44	0,620 7	0,613 7	0,609 4	0,607 7	0,606 1	0,605 2	0,604 5	0,603 1	0,602 2	0,601 4	0,601 1	0,600 8
0,46	0,622 8	0,615 2	0,610 6	0,608 7	0,607 0	0,606 1	0,605 3	0,603 7	0,602 7	0,601 9	0,601 5	0,601 2
0,48	0,625 1	0,616 9	0,611 8	0,609 8	0,607 9	0,606 9	0,606 1	0,604 3	0,603 3	0,602 3	0,601 9	0,601 5
0,50	0,627 6	0,618 6	0,613 1	0,610 9	0,608 8	0,607 8	0,606 9	0,605 0	0,603 8	0,602 7	0,602 2	0,601 8
0,51	0,628 9	0,619 5	0,613 8	0,611 5	0,609 3	0,608 2	0,607 3	0,605 3	0,604 0	0,602 9	0,602 4	0,601 9
0,52	0,630 2	0,620 4	0,614 4	0,612 1	0,609 8	0,608 7	0,607 7	0,605 6	0,604 3	0,603 0	0,602 5	0,602 0
0,53	0,631 6	0,621 3	0,615 1	0,612 6	0,610 3	0,609 1	0,608 0	0,605 9	0,604 5	0,603 2	0,602 6	0,602 1
0,54	0,633 0	0,622 3	0,615 8	0,613 2	0,610 8	0,609 5	0,608 4	0,606 1	0,604 7	0,603 3	0,602 7	0,602 1
0,55	0,634 4	0,623 2	0,616 5	0,613 8	0,611 2	0,609 9	0,608 8	0,606 4	0,604 9	0,603 4	0,602 8	0,602 2
0,56	—	0,624 2	0,617 2	0,614 3	0,611 7	0,610 3	0,609 1	0,606 6	0,605 0	0,603 5	0,602 8	0,602 2
0,57	—	0,625 2	0,617 9	0,614 9	0,612 1	0,610 7	0,609 5	0,606 9	0,605 2	0,603 6	0,602 8	0,602 2
0,58	—	0,626 2	0,618 5	0,615 5	0,612 6	0,611 1	0,609 8	0,607 0	0,605 3	0,603 6	0,602 8	0,602 1
0,59	—	0,627 2	0,619 2	0,616 0	0,613 0	0,611 4	0,610 1	0,607 2	0,605 4	0,603 6	0,602 8	0,602 0
0,60	—	0,628 2	0,619 8	0,616 5	0,613 4	0,611 7	0,610 3	0,607 3	0,605 4	0,603 5	0,602 7	0,601 9
0,61	—	0,629 2	0,620 5	0,617 0	0,613 7	0,612 0	0,610 6	0,607 4	0,605 4	0,603 4	0,602 5	0,601 7
0,62	—	0,630 2	0,621 1	0,617 5	0,614 0	0,612 3	0,610 8	0,607 5	0,605 4	0,603 3	0,602 3	0,601 4
0,63	—	0,631 2	0,621 7	0,617 9	0,614 3	0,612 5	0,610 9	0,607 5	0,605 2	0,603 0	0,602 1	0,601 1
0,64	—	0,632 1	0,622 2	0,618 3	0,614 5	0,612 6	0,611 0	0,607 4	0,605 1	0,602 8	0,601 7	0,600 7
0,65	—	0,633 1	0,622 7	0,618 6	0,614 7	0,612 7	0,611 0	0,607 3	0,604 8	0,602 4	0,601 3	0,600 2
0,66	—	0,634 0	0,623 2	0,618 9	0,614 8	0,612 8	0,611 0	0,607 1	0,604 5	0,602 0	0,600 8	0,599 7
0,67	—	0,634 8	0,623 6	0,619 1	0,614 9	0,612 7	0,610 8	0,606 8	0,604 1	0,601 4	0,600 2	0,599 0
0,68	—	0,635 7	0,623 9	0,619 3	0,614 9	0,612 6	0,610 6	0,606 4	0,603 6	0,600 8	0,599 5	0,598 3
0,69	—	0,636 4	0,624 2	0,619 3	0,614 7	0,612 4	0,610 4	0,605 9	0,603 0	0,600 1	0,598 7	0,597 4
0,70	—	0,637 2	0,624 4	0,619 3	0,614 5	0,612 1	0,610 0	0,605 3	0,602 3	0,599 2	0,597 8	0,596 4
0,71	—	0,637 8	0,624 5	0,619 2	0,614 2	0,611 7	0,609 4	0,604 6	0,601 4	0,598 2	0,596 7	0,595 3
0,72	—	0,638 3	0,624 4	0,618 9	0,613 8	0,611 1	0,608 8	0,603 8	0,600 5	0,597 1	0,595 5	0,594 0
0,73	—	0,638 8	0,624 3	0,618 6	0,613 2	0,610 4	0,608 0	0,602 8	0,599 3	0,595 8	0,594 2	0,592 6
0,74	—	0,639 1	0,624 0	0,618 1	0,612 5	0,609 6	0,607 1	0,601 6	0,598 0	0,594 3	0,592 6	0,591 0
0,75	—	0,639 4	0,623 6	0,617 4	0,611 6	0,608 6	0,606 0	0,600 3	0,596 5	0,592 7	0,590 9	0,589 2

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table 9 Orifice Plate with *D* and *D*/2 Tappings — Discharge Coefficient, *C*, for $D \geq 71.12$ mm

Diameter ratio	Discharge coefficient, *C*, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 3	0,598 7	0,597 7	0,597 3	0,596 9	0,596 7	0,596 6	0,596 3	0,596 2	0,596 1	0,596 1	0,596 0
0,12	0,601 0	0,599 1	0,597 9	0,597 5	0,597 1	0,596 9	0,596 7	0,596 4	0,596 2	0,596 1	0,596 1	0,596 1
0,14	0,601 6	0,599 5	0,598 2	0,597 7	0,597 2	0,597 0	0,596 8	0,596 5	0,596 3	0,596 2	0,596 1	0,596 1
0,16	0,602 3	0,600 0	0,598 5	0,598 0	0,597 4	0,597 2	0,597 0	0,596 6	0,596 4	0,596 2	0,596 2	0,596 2
0,18	0,602 9	0,600 4	0,598 9	0,598 2	0,597 7	0,597 4	0,597 1	0,596 7	0,596 5	0,596 3	0,596 3	0,596 3
0,20	0,603 7	0,600 9	0,599 2	0,598 5	0,597 9	0,597 6	0,597 4	0,596 9	0,596 6	0,596 4	0,596 4	0,596 4
0,22	0,604 4	0,601 5	0,599 6	0,598 9	0,598 2	0,597 9	0,597 6	0,597 1	0,596 8	0,596 6	0,596 5	0,596 5
0,24	0,605 3	0,602 1	0,600 1	0,599 3	0,598 5	0,598 2	0,597 9	0,597 3	0,597 0	0,596 7	0,596 7	0,596 6
0,26	0,606 2	0,602 7	0,600 6	0,599 7	0,598 9	0,598 5	0,598 2	0,597 5	0,597 2	0,596 9	0,596 9	0,596 8
0,28	0,607 2	0,603 4	0,601 1	0,600 2	0,599 3	0,598 9	0,598 5	0,597 8	0,597 5	0,597 2	0,597 1	0,597 0
0,30	0,608 2	0,604 2	0,601 7	0,600 7	0,599 8	0,599 3	0,598 9	0,598 2	0,597 8	0,597 4	0,597 3	0,597 3
0,32	0,609 4	0,605 1	0,602 4	0,601 3	0,600 3	0,599 8	0,599 4	0,598 6	0,598 1	0,597 7	0,597 6	0,597 5
0,34	0,610 7	0,606 0	0,603 1	0,602 0	0,600 9	0,600 4	0,599 9	0,599 0	0,598 5	0,598 1	0,597 9	0,597 8
0,36	0,612 1	0,607 1	0,604 0	0,602 7	0,601 6	0,601 0	0,600 5	0,599 5	0,598 9	0,598 4	0,598 3	0,598 1
0,38	0,613 7	0,608 2	0,604 9	0,603 5	0,602 3	0,601 6	0,601 1	0,600 0	0,599 4	0,598 8	0,598 6	0,598 5
0,40	0,615 3	0,609 5	0,605 9	0,604 4	0,603 1	0,602 4	0,601 8	0,600 6	0,599 9	0,599 3	0,599 1	0,598 9
0,42	0,617 2	0,610 9	0,607 0	0,605 4	0,603 9	0,603 2	0,602 5	0,601 2	0,600 5	0,599 8	0,599 5	0,599 3
0,44	0,619 2	0,612 4	0,608 2	0,606 5	0,604 9	0,604 1	0,603 4	0,601 9	0,601 1	0,600 3	0,600 0	0,599 7
0,46	0,621 4	0,614 0	0,609 4	0,607 6	0,605 9	0,605 0	0,604 2	0,602 7	0,601 7	0,600 8	0,600 5	0,600 2
0,48	0,623 8	0,615 7	0,610 8	0,608 8	0,607 0	0,606 0	0,605 2	0,603 5	0,602 4	0,601 4	0,601 0	0,600 6
0,50	0,626 4	0,617 6	0,612 3	0,610 1	0,608 1	0,607 1	0,606 2	0,604 3	0,603 1	0,602 0	0,601 6	0,601 1
0,51	0,627 8	0,618 6	0,613 1	0,610 8	0,608 7	0,607 6	0,606 7	0,604 7	0,603 5	0,602 3	0,601 9	0,601 4
0,52	0,629 2	0,619 7	0,613 9	0,611 5	0,609 3	0,608 2	0,607 2	0,605 2	0,603 9	0,602 7	0,602 1	0,601 6
0,53	0,630 7	0,620 7	0,614 7	0,612 3	0,610 0	0,608 8	0,607 8	0,605 6	0,604 3	0,603 0	0,602 4	0,601 9
0,54	0,632 2	0,621 8	0,615 5	0,613 0	0,610 6	0,609 4	0,608 3	0,606 1	0,604 7	0,603 3	0,602 7	0,602 1
0,55	0,633 7	0,622 9	0,616 4	0,613 8	0,611 3	0,610 0	0,608 9	0,606 5	0,605 0	0,603 6	0,603 0	0,602 4
0,56	—	0,624 1	0,617 3	0,614 5	0,611 9	0,610 6	0,609 5	0,607 0	0,605 4	0,603 9	0,603 2	0,602 6
0,57	—	0,625 3	0,618 2	0,615 3	0,612 6	0,611 2	0,610 0	0,607 5	0,605 8	0,604 2	0,603 5	0,602 8
0,58	—	0,626 5	0,619 1	0,616 1	0,613 3	0,611 9	0,610 6	0,607 9	0,606 2	0,604 5	0,603 8	0,603 0
0,59	—	0,627 7	0,620 0	0,616 9	0,614 0	0,612 5	0,611 2	0,608 4	0,606 6	0,604 8	0,604 0	0,603 2
0,60	—	0,629 0	0,621 0	0,617 7	0,614 7	0,613 1	0,611 8	0,608 8	0,607 0	0,605 1	0,604 2	0,603 4
0,61	—	0,630 3	0,621 9	0,618 6	0,615 4	0,613 8	0,612 4	0,609 3	0,607 3	0,605 3	0,604 4	0,603 6
0,62	—	0,631 6	0,622 9	0,619 4	0,616 1	0,614 4	0,612 9	0,609 7	0,607 7	0,605 6	0,604 6	0,603 7
0,63	—	0,632 9	0,623 8	0,620 2	0,616 8	0,615 0	0,613 5	0,610 2	0,608 0	0,605 8	0,604 8	0,603 9
0,64	—	0,634 3	0,624 8	0,621 0	0,617 5	0,615 6	0,614 0	0,610 6	0,608 3	0,606 0	0,605 0	0,603 9
0,65	—	0,635 6	0,625 8	0,621 9	0,618 2	0,616 2	0,614 6	0,610 9	0,608 6	0,606 2	0,605 1	0,604 0
0,66	—	0,637 0	0,626 8	0,622 7	0,618 8	0,616 8	0,615 1	0,611 3	0,608 8	0,606 3	0,605 1	0,604 0
0,67	—	0,638 4	0,627 7	0,623 5	0,619 5	0,617 4	0,615 6	0,611 6	0,609 0	0,606 4	0,605 2	0,604 0
0,68	—	0,639 8	0,628 7	0,624 3	0,620 1	0,617 9	0,616 1	0,612 0	0,609 2	0,606 5	0,605 2	0,603 9
0,69	—	0,641 1	0,629 6	0,625 0	0,620 7	0,618 5	0,616 5	0,612 2	0,609 4	0,606 5	0,605 1	0,603 8
0,70	—	0,642 5	0,630 5	0,625 8	0,621 3	0,618 9	0,616 9	0,612 5	0,609 5	0,606 5	0,605 1	0,603 7
0,71	—	0,643 9	0,631 5	0,626 5	0,621 8	0,619 4	0,617 3	0,612 7	0,609 6	0,606 4	0,604 9	0,603 5
0,72	—	0,645 3	0,632 3	0,627 2	0,622 3	0,619 8	0,617 6	0,612 8	0,609 6	0,606 3	0,604 7	0,603 2
0,73	—	0,646 7	0,633 2	0,627 9	0,622 8	0,620 2	0,617 9	0,612 9	0,609 6	0,606 1	0,604 5	0,602 9
0,74	—	0,648 0	0,634 0	0,628 5	0,623 3	0,620 6	0,618 2	0,613 0	0,609 5	0,605 9	0,604 2	0,602 5
0,75	—	0,649 4	0,634 9	0,629 1	0,623 7	0,620 9	0,618 4	0,613 0	0,609 4	0,605 6	0,603 8	0,602 1

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table 10 Orifice Plate with Flange Tappings — Discharge Coefficient, *C*, for $D = 50$ mm

Diameter ratio	Discharge coefficient, *C*, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,25	0,610 2	0,606 9	0,604 8	0,604 0	0,603 2	0,602 9	0,602 5	0,601 9	0,601 6	0,601 4	0,601 3	0,601 2
0,26	0,610 6	0,607 1	0,605 0	0,604 1	0,603 3	0,602 9	0,602 6	0,602 0	0,601 6	0,601 4	0,601 3	0,601 2
0,28	0,611 4	0,607 6	0,605 3	0,604 4	0,603 5	0,603 1	0,602 8	0,602 1	0,601 7	0,601 4	0,601 3	0,601 2
0,30	0,612 3	0,608 2	0,605 7	0,604 7	0,603 8	0,603 4	0,603 0	0,602 2	0,601 8	0,601 5	0,601 4	0,601 3
0,32	0,613 2	0,608 9	0,606 2	0,605 2	0,604 2	0,603 7	0,603 2	0,602 4	0,601 9	0,601 6	0,601 4	0,601 3
0,34	0,614 3	0,609 7	0,606 8	0,605 6	0,604 5	0,604 0	0,603 5	0,602 6	0,602 1	0,601 7	0,601 6	0,601 4
0,36	0,615 5	0,610 5	0,607 4	0,606 2	0,605 0	0,604 4	0,603 9	0,602 9	0,602 3	0,601 9	0,601 7	0,601 6
0,38	0,616 9	0,611 5	0,608 1	0,606 8	0,605 5	0,604 9	0,604 3	0,603 2	0,602 6	0,602 1	0,601 9	0,601 7
0,40	0,618 4	0,612 5	0,608 9	0,607 5	0,606 1	0,605 4	0,604 8	0,603 6	0,602 9	0,602 3	0,602 1	0,601 9
0,42	0,620 0	0,613 7	0,609 8	0,608 2	0,606 8	0,606 0	0,605 4	0,604 1	0,603 3	0,602 6	0,602 3	0,602 1
0,44	0,621 9	0,615 0	0,610 8	0,609 1	0,607 5	0,606 7	0,606 0	0,604 5	0,603 7	0,602 9	0,602 6	0,602 3
0,46	0,623 9	0,616 4	0,611 9	0,610 0	0,608 3	0,607 4	0,606 7	0,605 1	0,604 1	0,603 3	0,602 9	0,602 6
0,48	0,626 0	0,618 0	0,613 0	0,611 0	0,609 2	0,608 2	0,607 4	0,605 7	0,604 6	0,603 6	0,603 2	0,602 8
0,50	0,628 4	0,619 6	0,614 3	0,612 1	0,610 1	0,609 1	0,608 2	0,606 3	0,605 1	0,604 0	0,603 6	0,603 1
0,51	0,629 7	0,620 5	0,614 9	0,612 7	0,610 6	0,609 5	0,608 6	0,606 6	0,605 4	0,604 2	0,603 7	0,603 3
0,52	0,631 0	0,621 4	0,615 6	0,613 3	0,611 1	0,610 0	0,609 0	0,606 9	0,605 6	0,604 4	0,603 9	0,603 4
0,53	0,632 4	0,622 4	0,616 3	0,613 9	0,611 6	0,610 5	0,609 4	0,607 3	0,605 9	0,604 6	0,604 1	0,603 5
0,54	0,633 8	0,623 4	0,617 1	0,614 5	0,612 2	0,610 9	0,609 9	0,607 6	0,606 2	0,604 8	0,604 2	0,603 7
0,55	0,635 2	0,624 4	0,617 8	0,615 2	0,612 7	0,611 4	0,610 3	0,608 0	0,606 5	0,605 0	0,604 4	0,603 8
0,56	0,636 7	0,625 4	0,618 6	0,615 9	0,613 3	0,611 9	0,610 8	0,608 3	0,606 7	0,605 2	0,604 5	0,603 9
0,57	0,638 3	0,626 5	0,619 4	0,616 5	0,613 8	0,612 4	0,611 2	0,608 7	0,607 0	0,605 4	0,604 7	0,604 0
0,58	0,639 9	0,627 6	0,620 2	0,617 2	0,614 4	0,613 0	0,611 7	0,609 0	0,607 3	0,605 6	0,604 8	0,604 1
0,59	0,641 6	0,628 7	0,621 0	0,617 9	0,615 0	0,613 5	0,612 2	0,609 3	0,607 5	0,605 8	0,605 0	0,604 2
0,60	0,643 3	0,629 9	0,621 8	0,618 6	0,615 5	0,614 0	0,612 6	0,609 7	0,607 8	0,605 9	0,605 1	0,604 3
0,61	0,645 0	0,631 0	0,622 7	0,619 3	0,616 1	0,614 5	0,613 1	0,610 0	0,608 0	0,606 0	0,605 1	0,604 3
0,62	0,646 8	0,632 2	0,623 5	0,620 0	0,616 7	0,615 0	0,613 5	0,610 3	0,608 2	0,606 2	0,605 2	0,604 3
0,63	0,648 6	0,633 4	0,624 3	0,620 7	0,617 3	0,615 5	0,613 9	0,610 6	0,608 4	0,606 2	0,605 3	0,604 3
0,64	0,650 5	0,634 7	0,625 2	0,621 4	0,617 8	0,616 0	0,614 4	0,610 9	0,608 6	0,606 3	0,605 3	0,604 3
0,65	0,652 4	0,635 9	0,626 0	0,622 1	0,618 4	0,616 4	0,614 8	0,611 1	0,608 8	0,606 4	0,605 3	0,604 2
0,66	0,654 4	0,637 1	0,626 9	0,622 8	0,618 9	0,616 9	0,615 2	0,611 4	0,608 9	0,606 4	0,605 2	0,604 1
0,67	0,656 4	0,638 4	0,627 7	0,623 4	0,619 4	0,617 3	0,615 5	0,611 6	0,609 0	0,606 3	0,605 1	0,603 9
0,68	0,658 4	0,639 6	0,628 5	0,624 1	0,619 9	0,617 7	0,615 8	0,611 7	0,609 0	0,606 2	0,605 0	0,603 7
0,69	0,660 4	0,640 9	0,629 3	0,624 7	0,620 4	0,618 1	0,616 1	0,611 9	0,609 0	0,606 1	0,604 8	0,603 5
0,70	0,662 5	0,642 1	0,630 1	0,625 3	0,620 8	0,618 5	0,616 4	0,612 0	0,609 0	0,606 0	0,604 5	0,603 2
0,71	0,664 6	0,643 4	0,630 9	0,625 9	0,621 2	0,618 8	0,616 6	0,612 0	0,608 9	0,605 7	0,604 3	0,602 8
0,72	0,666 7	0,644 6	0,631 6	0,626 5	0,621 6	0,619 0	0,616 8	0,612 0	0,608 8	0,605 5	0,603 9	0,602 4
0,73	0,668 9	0,645 9	0,632 3	0,627 0	0,621 9	0,619 3	0,617 0	0,612 0	0,608 6	0,605 1	0,603 5	0,601 9
0,74	0,671 0	0,647 1	0,633 0	0,627 5	0,622 2	0,619 5	0,617 1	0,611 9	0,608 4	0,604 7	0,603 0	0,601 4
0,75	0,673 2	0,648 3	0,633 7	0,627 9	0,622 4	0,619 6	0,617 1	0,611 7	0,608 1	0,604 3	0,602 5	0,600 8

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table 11 Orifice Plate with Flange Tappings — Discharge Coefficient, C, for $D = 75$ mm

Diameter ratio	Discharge coefficient, C, for Re_D equal to										
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,17	0,602 7	0,600 3	0,598 8	0,598 2	0,597 7	0,597 4	0,597 2	0,596 7	0,596 5	0,596 4	0,596 4	0,596 3
0,18	0,603 1	0,600 5	0,599 0	0,598 4	0,597 8	0,597 5	0,597 3	0,596 8	0,596 6	0,596 4	0,596 4	0,596 4
0,20	0,603 8	0,601 1	0,599 4	0,598 7	0,598 1	0,597 7	0,597 5	0,597 0	0,596 7	0,596 6	0,596 5	0,596 5
0,22	0,604 6	0,601 6	0,599 8	0,599 0	0,598 4	0,598 0	0,597 7	0,597 2	0,596 9	0,596 7	0,596 7	0,596 6
0,24	0,605 4	0,602 2	0,600 2	0,599 4	0,598 7	0,598 3	0,598 0	0,597 4	0,597 1	0,596 9	0,596 9	0,596 8
0,26	0,606 4	0,602 9	0,600 7	0,599 9	0,599 1	0,598 7	0,598 4	0,597 7	0,597 4	0,597 1	0,597 0	0,597 0
0,28	0,607 4	0,603 6	0,601 3	0,600 4	0,599 5	0,599 1	0,598 7	0,598 0	0,597 6	0,597 4	0,597 3	0,597 2
0,30	0,608 4	0,604 4	0,601 9	0,600 9	0,600 0	0,599 5	0,599 1	0,598 4	0,597 9	0,597 6	0,597 5	0,597 4
0,32	0,609 6	0,605 3	0,602 6	0,601 5	0,600 5	0,600 0	0,599 6	0,598 8	0,598 3	0,597 9	0,597 8	0,597 7
0,34	0,610 9	0,606 2	0,603 3	0,602 2	0,601 1	0,600 6	0,600 1	0,599 2	0,598 7	0,598 3	0,598 1	0,598 0
0,36	0,612 3	0,607 3	0,604 2	0,602 9	0,601 7	0,601 2	0,600 7	0,599 7	0,599 1	0,598 6	0,598 4	0,598 3
0,38	0,613 9	0,608 4	0,605 1	0,603 7	0,602 5	0,601 8	0,601 3	0,600 2	0,599 5	0,599 0	0,598 8	0,598 6
0,40	0,615 5	0,609 7	0,606 0	0,604 6	0,603 2	0,602 5	0,602 0	0,600 8	0,600 0	0,599 4	0,599 2	0,599 0
0,42	0,617 4	0,611 0	0,607 1	0,605 5	0,604 1	0,603 3	0,602 7	0,601 4	0,600 6	0,599 9	0,599 6	0,599 4
0,44	0,619 4	0,612 5	0,608 3	0,606 6	0,605 0	0,604 2	0,603 5	0,602 0	0,601 2	0,600 4	0,600 1	0,599 8
0,46	0,621 6	0,614 1	0,609 5	0,607 7	0,605 9	0,605 1	0,604 3	0,602 7	0,601 8	0,600 9	0,600 5	0,600 2
0,48	0,623 9	0,615 8	0,610 8	0,608 9	0,607 0	0,606 0	0,605 2	0,603 5	0,602 4	0,601 4	0,601 0	0,600 6
0,50	0,626 4	0,617 6	0,612 3	0,610 1	0,608 1	0,607 0	0,606 1	0,604 2	0,603 1	0,602 0	0,601 5	0,601 1
0,51	0,627 8	0,618 6	0,613 0	0,610 7	0,608 6	0,607 5	0,606 6	0,604 6	0,603 4	0,602 2	0,601 7	0,601 3
0,52	0,629 2	0,619 6	0,613 8	0,611 4	0,609 2	0,608 1	0,607 1	0,605 0	0,603 7	0,602 5	0,602 0	0,601 5
0,53	0,630 6	0,620 6	0,614 5	0,612 1	0,609 8	0,608 6	0,607 6	0,605 4	0,604 1	0,602 8	0,602 2	0,601 7
0,54	0,632 1	0,621 6	0,615 3	0,612 8	0,610 4	0,609 2	0,608 1	0,605 8	0,604 4	0,603 0	0,602 4	0,601 9
0,55	0,633 6	0,622 7	0,616 1	0,613 5	0,611 0	0,609 7	0,608 6	0,606 2	0,604 7	0,603 3	0,602 7	0,602 1
0,56	0,635 2	0,623 8	0,617 0	0,614 2	0,611 6	0,610 3	0,609 1	0,606 6	0,605 1	0,603 5	0,602 9	0,602 2
0,57	0,636 8	0,624 9	0,617 8	0,614 9	0,612 2	0,610 8	0,609 6	0,607 0	0,605 4	0,603 8	0,603 1	0,602 4
0,58	0,638 5	0,626 1	0,618 6	0,615 6	0,612 8	0,611 4	0,610 1	0,607 4	0,605 7	0,604 0	0,603 2	0,602 5
0,59	0,640 2	0,627 3	0,619 5	0,616 4	0,613 4	0,611 9	0,610 6	0,607 8	0,606 0	0,604 2	0,603 4	0,602 6
0,60	0,641 9	0,628 4	0,620 3	0,617 1	0,614 0	0,612 5	0,611 1	0,608 2	0,606 3	0,604 4	0,603 5	0,602 7
0,61	0,643 7	0,629 6	0,621 2	0,617 8	0,614 6	0,613 0	0,611 6	0,608 5	0,606 5	0,604 5	0,603 6	0,602 8
0,62	0,645 5	0,630 9	0,622 1	0,618 6	0,615 2	0,613 5	0,612 0	0,608 8	0,606 7	0,604 7	0,603 7	0,602 8
0,63	—	0,632 1	0,622 9	0,619 3	0,615 8	0,614 0	0,612 5	0,609 1	0,606 9	0,604 8	0,603 8	0,602 8
0,64	—	0,633 3	0,623 8	0,620 0	0,616 4	0,614 5	0,612 9	0,609 4	0,607 1	0,604 8	0,603 8	0,602 8
0,65	—	0,634 6	0,624 6	0,620 7	0,616 9	0,615 0	0,613 3	0,609 7	0,607 3	0,604 9	0,603 8	0,602 7
0,66	—	0,635 8	0,625 5	0,621 3	0,617 4	0,615 4	0,613 7	0,609 9	0,607 4	0,604 8	0,603 7	0,602 6
0,67	—	0,637 0	0,626 3	0,622 0	0,617 9	0,615 8	0,614 0	0,610 0	0,607 4	0,604 8	0,603 6	0,602 4
0,68	—	0,638 2	0,627 0	0,622 6	0,618 4	0,616 2	0,614 3	0,610 2	0,607 4	0,604 6	0,603 4	0,602 1
0,69	—	0,639 5	0,627 8	0,623 2	0,618 8	0,616 5	0,614 5	0,610 2	0,607 4	0,604 5	0,603 1	0,601 8
0,70	—	0,640 7	0,628 5	0,623 7	0,619 1	0,616 8	0,614 7	0,610 2	0,607 3	0,604 2	0,602 8	0,601 4
0,71	—	0,641 8	0,629 2	0,624 2	0,619 4	0,617 0	0,614 8	0,610 2	0,607 1	0,603 9	0,602 4	0,601 0
0,72	—	0,643 0	0,629 8	0,624 6	0,619 7	0,617 1	0,614 9	0,610 1	0,606 8	0,603 5	0,601 9	0,600 4
0,73	—	0,644 1	0,630 4	0,625 0	0,619 9	0,617 2	0,614 9	0,609 9	0,606 5	0,603 0	0,601 4	0,599 8
0,74	—	0,645 1	0,631 0	0,625 3	0,620 0	0,617 3	0,614 9	0,609 6	0,606 1	0,602 5	0,600 8	0,599 1
0,75	—	0,646 2	0,631 4	0,625 6	0,620 1	0,617 2	0,614 7	0,609 3	0,605 6	0,601 8	0,600 0	0,598 3

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table 12 Orifice Plate with Flange Tappings — Discharge Coefficient, C, for $D = 100$ mm

Diameter ratio	Discharge coefficient, C, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,13	0,601 4	0,599 4	0,598 2	0,597 7	0,597 3	0,597 1	0,596 9	0,596 6	0,596 4	0,596 3	0,596 2	0,596 2
0,14	0,601 8	0,599 7	0,598 4	0,597 9	0,597 4	0,597 2	0,597 0	0,596 6	0,596 4	0,596 3	0,596 3	0,596 3
0,16	0,602 5	0,600 1	0,598 7	0,598 1	0,597 6	0,597 4	0,597 2	0,596 8	0,596 5	0,596 4	0,596 4	0,596 4
0,18	0,603 2	0,600 6	0,599 1	0,598 5	0,597 9	0,597 6	0,597 4	0,596 9	0,596 7	0,596 5	0,596 5	0,596 5
0,20	0,603 9	0,601 2	0,599 5	0,598 8	0,598 2	0,597 9	0,597 6	0,597 1	0,596 9	0,596 7	0,596 6	0,596 6
0,22	0,604 7	0,601 7	0,599 9	0,599 2	0,598 5	0,598 1	0,597 9	0,597 3	0,597 0	0,596 9	0,596 8	0,596 8
0,24	0,605 6	0,602 4	0,600 4	0,599 6	0,598 8	0,598 5	0,598 2	0,597 6	0,597 3	0,597 0	0,597 0	0,596 9
0,26	0,606 5	0,603 0	0,600 9	0,600 0	0,599 2	0,598 8	0,598 5	0,597 9	0,597 5	0,597 3	0,597 2	0,597 1
0,28	0,607 5	0,603 8	0,601 4	0,600 5	0,599 7	0,599 2	0,598 9	0,598 2	0,597 8	0,597 5	0,597 4	0,597 4
0,30	0,608 6	0,604 6	0,602 1	0,601 1	0,600 2	0,599 7	0,599 3	0,598 5	0,598 1	0,597 8	0,597 7	0,597 6
0,32	0,609 8	0,605 4	0,602 8	0,601 7	0,600 7	0,600 2	0,599 8	0,598 9	0,598 5	0,598 1	0,598 0	0,597 9
0,34	0,611 1	0,606 4	0,603 5	0,602 4	0,601 3	0,600 7	0,600 3	0,599 4	0,598 8	0,598 4	0,598 3	0,598 2
0,36	0,612 5	0,607 5	0,604 3	0,603 1	0,601 9	0,601 3	0,600 8	0,599 8	0,599 3	0,598 8	0,598 6	0,598 5
0,38	0,614 1	0,608 6	0,605 2	0,603 9	0,602 6	0,602 0	0,601 5	0,600 4	0,599 7	0,599 2	0,599 0	0,598 8
0,40	0,615 7	0,609 9	0,606 2	0,604 8	0,603 4	0,602 7	0,602 1	0,600 9	0,600 2	0,599 6	0,599 4	0,599 2
0,42	0,617 6	0,611 2	0,607 3	0,605 7	0,604 2	0,603 5	0,602 9	0,601 5	0,600 8	0,600 1	0,599 8	0,599 6
0,44	0,619 6	0,612 7	0,608 4	0,606 7	0,605 1	0,604 3	0,603 6	0,602 2	0,601 3	0,600 5	0,600 2	0,600 0
0,46	0,621 7	0,614 2	0,609 7	0,607 8	0,606 1	0,605 2	0,604 4	0,602 9	0,601 9	0,601 0	0,600 7	0,600 3
0,48	0,624 1	0,615 9	0,611 0	0,609 0	0,607 1	0,606 1	0,605 3	0,603 6	0,602 5	0,601 5	0,601 1	0,600 7
0,50	0,626 6	0,617 7	0,612 4	0,610 2	0,608 1	0,607 1	0,606 2	0,604 3	0,603 1	0,602 0	0,601 6	0,601 1
0,51	0,627 9	0,618 7	0,613 1	0,610 8	0,608 7	0,607 6	0,606 7	0,604 7	0,603 4	0,602 3	0,601 8	0,601 3
0,52	0,629 3	0,619 7	0,613 8	0,611 5	0,609 2	0,608 1	0,607 1	0,605 1	0,603 8	0,602 5	0,602 0	0,601 5
0,53	0,630 7	0,620 7	0,614 6	0,612 1	0,609 8	0,608 6	0,607 6	0,605 4	0,604 1	0,602 8	0,602 2	0,601 7
0,54	0,632 2	0,621 7	0,615 3	0,612 8	0,610 4	0,609 1	0,608 1	0,605 8	0,604 4	0,603 0	0,602 4	0,601 8
0,55	—	0,622 7	0,616 1	0,613 5	0,610 9	0,609 7	0,608 5	0,606 2	0,604 7	0,603 2	0,602 6	0,602 0
0,56	—	0,623 8	0,616 9	0,614 1	0,611 5	0,610 2	0,609 0	0,606 5	0,605 0	0,603 4	0,602 8	0,602 1
0,57	—	0,624 9	0,617 7	0,614 8	0,612 1	0,610 7	0,609 5	0,606 9	0,605 2	0,603 6	0,602 9	0,602 2
0,58	—	0,626 0	0,618 5	0,615 5	0,612 7	0,611 2	0,610 0	0,607 2	0,605 5	0,603 8	0,603 1	0,602 3
0,59	—	0,627 1	0,619 3	0,616 2	0,613 2	0,611 7	0,610 4	0,607 6	0,605 8	0,604 0	0,603 2	0,602 4
0,60	—	0,628 3	0,620 1	0,616 9	0,613 8	0,612 2	0,610 8	0,607 9	0,606 0	0,604 1	0,603 3	0,602 5
0,61	—	0,629 4	0,620 9	0,617 6	0,614 3	0,612 7	0,611 3	0,608 2	0,606 2	0,604 2	0,603 3	0,602 5
0,62	—	0,630 6	0,621 8	0,618 2	0,614 9	0,613 2	0,611 7	0,608 5	0,606 4	0,604 3	0,603 3	0,602 4
0,63	—	0,631 8	0,622 6	0,618 9	0,615 4	0,613 6	0,612 0	0,608 7	0,606 5	0,604 3	0,603 3	0,602 4
0,64	—	0,632 9	0,623 3	0,619 5	0,615 9	0,614 0	0,612 4	0,608 9	0,606 6	0,604 3	0,603 3	0,602 2
0,65	—	0,634 1	0,624 1	0,620 1	0,616 3	0,614 4	0,612 7	0,609 1	0,606 7	0,604 2	0,603 1	0,602 1
0,66	—	0,635 3	0,624 9	0,620 7	0,616 8	0,614 8	0,613 0	0,609 2	0,606 7	0,604 1	0,603 0	0,601 9
0,67	—	0,636 4	0,625 6	0,621 2	0,617 2	0,615 1	0,613 2	0,609 2	0,606 6	0,604 0	0,602 8	0,601 6
0,68	—	0,637 5	0,626 3	0,621 8	0,617 5	0,615 3	0,613 4	0,609 3	0,606 5	0,603 7	0,602 5	0,601 2
0,69	—	0,638 7	0,626 9	0,622 2	0,617 8	0,615 5	0,613 5	0,609 2	0,606 3	0,603 4	0,602 1	0,600 8
0,70	—	0,639 7	0,627 5	0,622 6	0,618 0	0,615 7	0,613 6	0,609 1	0,606 1	0,603 1	0,601 6	0,600 3
0,71	—	0,640 8	0,628 0	0,623 0	0,618 2	0,615 7	0,613 6	0,608 9	0,605 8	0,602 6	0,601 1	0,599 7
0,72	—	0,641 8	0,628 5	0,623 3	0,618 3	0,615 7	0,613 5	0,608 6	0,605 4	0,602 0	0,600 5	0,599 0
0,73	—	0,642 8	0,629 0	0,623 5	0,618 3	0,615 7	0,613 3	0,608 3	0,604 9	0,601 4	0,599 8	0,598 2
0,74	—	0,643 7	0,629 3	0,623 6	0,618 3	0,615 5	0,613 1	0,607 8	0,604 3	0,600 6	0,598 9	0,597 3
0,75	—	0,644 5	0,629 6	0,623 7	0,618 1	0,615 3	0,612 7	0,607 2	0,603 6	0,599 8	0,598 0	0,596 2

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table 13 Orifice Plate with Flange Tappings — Discharge Coefficient, *C*, for *D* = 150 mm

Diameter ratio	Discharge coefficient, C, for Re_D equal to										
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 5	0,598 8	0,597 8	0,597 4	0,597 1	0,596 9	0,596 7	0,596 5	0,596 3	0,596 2	0,596 2	0,596 2
0,12	0,601 2	0,599 3	0,598 1	0,597 7	0,597 3	0,597 1	0,596 9	0,596 6	0,596 4	0,596 3	0,596 3	0,596 3
0,14	0,601 8	0,599 8	0,598 5	0,598 0	0,597 5	0,597 3	0,597 1	0,596 7	0,596 5	0,596 4	0,596 4	0,596 4
0,16	0,602 5	0,600 2	0,598 8	0,598 2	0,597 7	0,597 5	0,597 3	0,596 9	0,596 6	0,596 5	0,596 5	0,596 5
0,18	0,603 3	0,600 7	0,599 2	0,598 6	0,598 0	0,597 7	0,597 5	0,597 0	0,596 8	0,596 7	0,596 6	0,596 6
0,20	0,604 1	0,601 3	0,599 6	0,598 9	0,598 3	0,598 0	0,597 7	0,597 2	0,597 0	0,596 8	0,596 8	0,596 7
0,22	0,604 9	0,601 9	0,600 0	0,599 3	0,598 6	0,598 3	0,598 0	0,597 5	0,597 2	0,597 0	0,596 9	0,596 9
0,24	0,605 7	0,602 5	0,600 5	0,599 7	0,599 0	0,598 6	0,598 3	0,597 7	0,597 4	0,597 2	0,597 1	0,597 1
0,26	0,606 7	0,603 2	0,601 1	0,600 2	0,599 4	0,599 0	0,598 7	0,598 0	0,597 7	0,597 4	0,597 4	0,597 3
0,28	0,607 7	0,603 9	0,601 6	0,600 7	0,599 8	0,599 4	0,599 1	0,598 4	0,598 0	0,597 7	0,597 6	0,597 5
0,30	0,608 8	0,604 8	0,602 3	0,601 3	0,600 3	0,599 9	0,599 5	0,598 7	0,598 3	0,598 0	0,597 9	0,597 8
0,32	0,610 0	0,605 6	0,603 0	0,601 9	0,600 9	0,600 4	0,600 0	0,599 1	0,598 7	0,598 3	0,598 2	0,598 1
0,34	0,611 3	0,606 6	0,603 7	0,602 6	0,601 5	0,600 9	0,600 5	0,599 6	0,599 0	0,598 6	0,598 5	0,598 4
0,36	0,612 7	0,607 7	0,604 5	0,603 3	0,602 1	0,601 5	0,601 0	0,600 0	0,599 5	0,599 0	0,598 8	0,598 7
0,38	0,614 3	0,608 8	0,605 4	0,604 1	0,602 8	0,602 2	0,601 7	0,600 6	0,599 9	0,599 4	0,599 2	0,599 0
0,40	0,616 0	0,610 1	0,606 4	0,605 0	0,603 6	0,602 9	0,602 3	0,601 1	0,600 4	0,599 8	0,599 6	0,599 4
0,42	0,617 8	0,611 4	0,607 5	0,605 9	0,604 4	0,603 7	0,603 0	0,601 7	0,600 9	0,600 2	0,600 0	0,599 7
0,44	0,619 8	0,612 8	0,608 6	0,606 9	0,605 3	0,604 5	0,603 8	0,602 3	0,601 5	0,600 7	0,600 4	0,600 1
0,46	—	0,614 4	0,609 8	0,607 9	0,606 2	0,605 3	0,604 6	0,603 0	0,602 0	0,601 1	0,600 8	0,600 5
0,48	—	0,616 0	0,611 1	0,609 1	0,607 2	0,606 2	0,605 4	0,603 6	0,602 6	0,601 6	0,601 2	0,600 8
0,50	—	0,617 8	0,612 4	0,610 2	0,608 2	0,607 1	0,606 2	0,604 3	0,603 1	0,602 1	0,601 6	0,601 2
0,51	—	0,618 7	0,613 1	0,610 8	0,608 7	0,607 6	0,606 7	0,604 7	0,603 4	0,602 3	0,601 8	0,601 3
0,52	—	0,619 7	0,613 8	0,611 4	0,609 2	0,608 1	0,607 1	0,605 0	0,603 7	0,602 5	0,602 0	0,601 5
0,53	—	0,620 6	0,614 5	0,612 1	0,609 7	0,608 6	0,607 5	0,605 4	0,604 0	0,602 7	0,602 1	0,601 6
0,54	—	0,621 6	0,615 3	0,612 7	0,610 3	0,609 0	0,608 0	0,605 7	0,604 2	0,602 9	0,602 3	0,601 7
0,55	—	0,622 6	0,616 0	0,613 3	0,610 8	0,609 5	0,608 4	0,606 0	0,604 5	0,603 1	0,602 4	0,601 8
0,56	—	0,623 7	0,616 7	0,614 0	0,611 3	0,610 0	0,608 8	0,606 3	0,604 7	0,603 2	0,602 5	0,601 9
0,57	—	0,624 7	0,617 5	0,614 6	0,611 9	0,610 5	0,609 2	0,606 6	0,605 0	0,603 4	0,602 6	0,602 0
0,58	—	0,625 8	0,618 2	0,615 2	0,612 4	0,610 9	0,609 6	0,606 9	0,605 2	0,603 5	0,602 7	0,602 0
0,59	—	0,626 9	0,619 0	0,615 9	0,612 9	0,611 4	0,610 0	0,607 2	0,605 4	0,603 6	0,602 8	0,602 0
0,60	—	0,628 0	0,619 8	0,616 5	0,613 4	0,611 8	0,610 4	0,607 4	0,605 5	0,603 6	0,602 8	0,602 0
0,61	—	0,629 0	0,620 5	0,617 1	0,613 8	0,612 2	0,610 7	0,607 6	0,605 6	0,603 7	0,602 8	0,601 9
0,62	—	0,630 1	0,621 2	0,617 7	0,614 3	0,612 6	0,611 1	0,607 8	0,605 7	0,603 6	0,602 7	0,601 8
0,63	—	—	0,621 9	0,618 2	0,614 7	0,612 9	0,611 4	0,608 0	0,605 8	0,603 6	0,602 6	0,601 6
0,64	—	—	0,622 6	0,618 8	0,615 1	0,613 2	0,611 6	0,608 1	0,605 8	0,603 5	0,602 4	0,601 4
0,65	—	—	0,623 3	0,619 3	0,615 5	0,613 5	0,611 8	0,608 1	0,605 7	0,603 3	0,602 2	0,601 1
0,66	—	—	0,623 9	0,619 7	0,615 8	0,613 8	0,612 0	0,608 1	0,605 6	0,603 1	0,601 9	0,600 8
0,67	—	—	0,624 5	0,620 2	0,616 0	0,613 9	0,612 1	0,608 1	0,605 4	0,602 8	0,601 6	0,600 4
0,68	—	—	0,625 1	0,620 5	0,616 2	0,614 0	0,612 1	0,607 9	0,605 2	0,602 4	0,601 1	0,599 9
0,69	—	—	0,625 6	0,620 9	0,616 4	0,614 1	0,612 1	0,607 7	0,604 9	0,601 9	0,600 6	0,599 3
0,70	—	—	0,626 0	0,621 1	0,616 5	0,614 1	0,612 0	0,607 4	0,604 4	0,601 4	0,600 0	0,598 6
0,71	—	—	0,626 4	0,621 3	0,616 5	0,614 0	0,611 8	0,607 1	0,603 9	0,600 7	0,599 3	0,597 8
0,72	—	—	0,626 7	0,621 4	0,616 4	0,613 8	0,611 5	0,606 6	0,603 3	0,600 0	0,598 4	0,596 9
0,73	—	—	0,626 9	0,621 4	0,616 2	0,613 5	0,611 1	0,606 0	0,602 6	0,599 1	0,597 5	0,595 9
0,74	—	—	0,627 1	0,621 3	0,615 9	0,613 1	0,610 6	0,605 3	0,601 7	0,598 1	0,596 4	0,594 7
0,75	—	—	0,627 1	0,621 1	0,615 4	0,612 5	0,610 0	0,604 4	0,600 7	0,596 9	0,595 1	0,593 4

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table 14 Orifice Plate with Flange Tappings — Discharge Coefficient, *C*, for $D = 200$ mm

Diameter ratio	Discharge coefficient, *C*, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 5	0,598 9	0,597 9	0,597 5	0,597 1	0,596 9	0,596 8	0,596 5	0,596 3	0,596 3	0,596 2	0,596 2
0,12	0,601 2	0,599 3	0,598 2	0,597 7	0,597 3	0,597 1	0,596 9	0,596 6	0,596 4	0,596 3	0,596 3	0,596 3
0,14	0,601 9	0,599 8	0,598 5	0,598 0	0,597 5	0,597 3	0,597 1	0,596 7	0,596 6	0,596 4	0,596 4	0,596 4
0,16	0,602 6	0,600 3	0,598 9	0,598 3	0,597 8	0,597 5	0,597 3	0,596 9	0,596 7	0,596 6	0,596 5	0,596 5
0,18	0,603 3	0,600 8	0,599 3	0,598 6	0,598 1	0,597 8	0,597 5	0,597 1	0,596 9	0,596 7	0,596 7	0,596 7
0,20	0,604 1	0,601 4	0,599 7	0,599 0	0,598 4	0,598 1	0,597 8	0,597 3	0,597 1	0,596 9	0,596 8	0,596 8
0,22	0,605 0	0,602 0	0,600 1	0,599 4	0,598 7	0,598 4	0,598 1	0,597 6	0,597 3	0,597 1	0,597 0	0,597 0
0,24	0,605 8	0,602 6	0,600 6	0,599 8	0,599 1	0,598 7	0,598 4	0,597 8	0,597 5	0,597 3	0,597 2	0,597 2
0,26	0,606 8	0,603 3	0,601 1	0,600 3	0,599 5	0,599 1	0,598 8	0,598 1	0,597 8	0,597 5	0,597 5	0,597 4
0,28	0,607 8	0,604 1	0,601 7	0,600 8	0,600 0	0,599 5	0,599 2	0,598 5	0,598 1	0,597 8	0,597 7	0,597 6
0,30	0,608 9	0,604 9	0,602 4	0,601 4	0,600 5	0,600 0	0,599 6	0,598 8	0,598 4	0,598 1	0,598 0	0,597 9
0,32	0,610 1	0,605 8	0,603 1	0,602 0	0,601 0	0,600 5	0,600 1	0,599 2	0,598 8	0,598 4	0,598 3	0,598 2
0,34	0,611 4	0,606 7	0,603 8	0,602 7	0,601 6	0,601 1	0,600 6	0,599 7	0,599 2	0,598 7	0,598 6	0,598 5
0,36	0,612 8	0,607 8	0,604 7	0,603 4	0,602 2	0,601 7	0,601 2	0,600 2	0,599 6	0,599 1	0,598 9	0,598 8
0,38	0,614 4	0,608 9	0,605 6	0,604 2	0,602 9	0,602 3	0,601 8	0,600 7	0,600 0	0,599 5	0,599 3	0,599 1
0,40	—	0,610 2	0,606 5	0,605 1	0,603 7	0,603 0	0,602 4	0,601 2	0,600 5	0,599 9	0,599 7	0,599 5
0,42	—	0,611 5	0,607 6	0,606 0	0,604 5	0,603 8	0,603 1	0,601 8	0,601 0	0,600 3	0,600 1	0,599 8
0,44	—	0,612 9	0,608 7	0,607 0	0,605 4	0,604 5	0,603 8	0,602 4	0,601 5	0,600 8	0,600 4	0,600 2
0,46	—	0,614 5	0,609 9	0,608 0	0,606 3	0,605 4	0,604 6	0,603 0	0,602 1	0,601 2	0,600 8	0,600 5
0,48	—	0,616 1	0,611 1	0,609 1	0,607 2	0,606 2	0,605 4	0,603 7	0,602 6	0,601 6	0,601 2	0,600 9
0,50	—	0,617 9	0,612 4	0,610 2	0,608 2	0,607 1	0,606 2	0,604 3	0,603 2	0,602 1	0,601 6	0,601 2
0,51	—	0,618 8	0,613 1	0,610 8	0,608 7	0,607 6	0,606 7	0,604 7	0,603 4	0,602 3	0,601 8	0,601 3
0,52	—	0,619 7	0,613 8	0,611 4	0,609 2	0,608 1	0,607 1	0,605 0	0,603 7	0,602 5	0,601 9	0,601 4
0,53	—	0,620 6	0,614 5	0,612 0	0,609 7	0,608 5	0,607 5	0,605 3	0,603 9	0,602 6	0,602 1	0,601 5
0,54	—	0,621 6	0,615 2	0,612 6	0,610 2	0,609 0	0,607 9	0,605 6	0,604 2	0,602 8	0,602 2	0,601 6
0,55	—	—	0,615 9	0,613 2	0,610 7	0,609 4	0,608 3	0,605 9	0,604 4	0,603 0	0,602 3	0,601 7
0,56	—	—	0,616 6	0,613 8	0,611 2	0,609 9	0,608 7	0,606 2	0,604 6	0,603 1	0,602 4	0,601 8
0,57	—	—	0,617 4	0,614 5	0,611 7	0,610 3	0,609 1	0,606 5	0,604 8	0,603 2	0,602 5	0,601 8
0,58	—	—	0,618 1	0,615 1	0,612 2	0,610 7	0,609 4	0,606 7	0,605 0	0,603 3	0,602 5	0,601 8
0,59	—	—	0,618 8	0,615 6	0,612 7	0,611 1	0,609 8	0,607 0	0,605 1	0,603 3	0,602 5	0,601 8
0,60	—	—	0,619 5	0,616 2	0,613 1	0,611 5	0,610 1	0,607 2	0,605 2	0,603 4	0,602 5	0,601 7
0,61	—	—	0,620 2	0,616 8	0,613 5	0,611 9	0,610 4	0,607 3	0,605 3	0,603 3	0,602 4	0,601 6
0,62	—	—	0,620 9	0,617 3	0,613 9	0,612 2	0,610 7	0,607 5	0,605 3	0,603 3	0,602 3	0,601 4
0,63	—	—	0,621 6	0,617 8	0,614 3	0,612 5	0,610 9	0,607 6	0,605 3	0,603 2	0,602 2	0,601 2
0,64	—	—	0,622 2	0,618 3	0,614 7	0,612 8	0,611 1	0,607 6	0,605 3	0,603 0	0,601 9	0,600 9
0,65	—	—	0,622 8	0,618 8	0,615 0	0,613 0	0,611 3	0,607 6	0,605 2	0,602 8	0,601 6	0,600 6
0,66	—	—	0,623 4	0,619 2	0,615 2	0,613 2	0,611 4	0,607 5	0,605 0	0,602 5	0,601 3	0,600 2
0,67	—	—	0,623 9	0,619 5	0,615 4	0,613 3	0,611 4	0,607 4	0,604 7	0,602 1	0,600 9	0,599 7
0,68	—	—	0,624 4	0,619 8	0,615 5	0,613 3	0,611 4	0,607 2	0,604 4	0,601 6	0,600 3	0,599 1
0,69	—	—	0,624 8	0,620 1	0,615 6	0,613 3	0,611 2	0,606 9	0,604 0	0,601 1	0,599 7	0,598 4
0,70	—	—	0,625 2	0,620 2	0,615 5	0,613 1	0,611 0	0,606 5	0,603 5	0,600 4	0,599 0	0,597 6
0,71	—	—	0,625 5	0,620 3	0,615 4	0,612 9	0,610 7	0,606 0	0,602 8	0,599 6	0,598 2	0,596 7
0,72	—	—	0,625 7	0,620 3	0,615 2	0,612 6	0,610 3	0,605 4	0,602 1	0,598 8	0,597 2	0,595 7
0,73	—	—	0,625 8	0,620 2	0,614 9	0,612 2	0,609 8	0,604 7	0,601 2	0,597 7	0,596 1	0,594 5
0,74	—	—	0,625 8	0,619 9	0,614 5	0,611 6	0,609 2	0,603 8	0,600 2	0,596 6	0,594 9	0,593 2
0,75	—	—	0,625 6	0,619 6	0,613 9	0,611 0	0,608 4	0,602 8	0,599 1	0,595 3	0,593 5	0,591 7

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table 15 Orifice Plate with Flange Tappings — Discharge Coefficient, *C*, for *D* = 250 mm

Diameter ratio	Discharge coefficient, *C*, for Re_D equal to										
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 5	0,598 9	0,597 9	0,597 5	0,597 1	0,596 9	0,596 8	0,596 5	0,5964	0,596 3	0,596 3	0,596 3
0,12	0,601 2	0,599 4	0,598 2	0,597 7	0,597 3	0,597 1	0,597 0	0,596 6	0,5965	0,596 4	0,596 3	0,596 3
0,14	0,601 9	0,599 8	0,598 5	0,598 0	0,597 6	0,597 3	0,597 1	0,596 8	0,5966	0,596 5	0,596 5	0,596 4
0,16	0,602 6	0,600 3	0,598 9	0,598 3	0,597 8	0,597 6	0,597 4	0,596 9	0,5967	0,596 6	0,596 6	0,596 6
0,18	0,603 4	0,600 9	0,599 3	0,598 7	0,598 1	0,597 8	0,597 6	0,597 1	0,5969	0,596 8	0,596 7	0,596 7
0,20	0,604 2	0,601 4	0,599 7	0,599 0	0,598 4	0,598 1	0,597 9	0,597 4	0,5971	0,596 9	0,596 9	0,596 9
0,22	0,605 0	0,602 0	0,600 2	0,599 4	0,598 8	0,598 4	0,598 1	0,597 6	0,5973	0,597 1	0,597 1	0,597 1
0,24	0,605 9	0,602 7	0,600 7	0,599 9	0,599 1	0,598 8	0,598 5	0,597 9	0,5976	0,597 4	0,597 3	0,597 3
0,26	0,606 8	0,603 4	0,601 2	0,600 4	0,599 6	0,599 2	0,598 8	0,598 2	0,5978	0,597 6	0,597 5	0,597 5
0,28	0,607 9	0,604 1	0,601 8	0,600 9	0,600 0	0,599 6	0,599 2	0,598 5	0,5981	0,597 9	0,597 8	0,597 7
0,30	0,609 0	0,604 9	0,602 5	0,601 5	0,600 5	0,600 1	0,599 7	0,598 9	0,5985	0,598 2	0,598 1	0,598 0
0,32	0,610 2	0,605 8	0,603 2	0,602 1	0,601 1	0,600 6	0,600 2	0,599 3	0,5988	0,598 5	0,598 4	0,598 3
0,34	0,611 5	0,606 8	0,603 9	0,602 8	0,601 7	0,601 1	0,600 7	0,599 8	0,5992	0,598 8	0,598 7	0,598 6
0,36	—	0,607 9	0,604 7	0,603 5	0,602 3	0,601 7	0,601 2	0,600 2	0,5997	0,599 2	0,599 0	0,598 9
0,38	—	0,609 0	0,605 6	0,604 3	0,603 0	0,602 4	0,601 8	0,600 7	0,6001	0,599 6	0,599 4	0,599 2
0,40	—	0,610 2	0,606 6	0,605 1	0,603 8	0,603 1	0,602 5	0,601 3	0,6006	0,600 0	0,599 7	0,599 5
0,42	—	0,611 6	0,607 6	0,606 1	0,604 6	0,603 8	0,603 2	0,601 9	0,6011	0,600 4	0,600 1	0,599 9
0,44	—	0,613 0	0,608 7	0,607 0	0,605 4	0,604 6	0,603 9	0,602 5	0,6016	0,600 8	0,600 5	0,600 2
0,46	—	0,614 5	0,609 9	0,608 1	0,606 3	0,605 4	0,604 7	0,603 1	0,6021	0,601 2	0,600 9	0,600 6
0,48	—	0,616 2	0,611 2	0,609 1	0,607 2	0,606 3	0,605 5	0,603 7	0,6026	0,601 7	0,601 3	0,600 9
0,50	—	—	0,612 5	0,610 3	0,608 2	0,607 2	0,606 3	0,604 4	0,6032	0,602 1	0,601 6	0,601 2
0,51	—	—	0,613 1	0,610 8	0,608 7	0,607 6	0,606 7	0,604 7	0,6034	0,602 3	0,601 8	0,601 3
0,52	—	—	0,613 8	0,611 4	0,609 2	0,608 1	0,607 1	0,605 0	0,6037	0,602 4	0,601 9	0,601 4
0,53	—	—	0,614 5	0,612 0	0,609 7	0,608 5	0,607 5	0,605 3	0,6039	0,602 6	0,602 1	0,601 5
0,54	—	—	0,615 2	0,612 6	0,610 2	0,608 9	0,607 9	0,605 6	0,6041	0,602 8	0,602 2	0,601 6
0,55	—	—	0,615 9	0,613 2	0,610 7	0,609 4	0,608 3	0,605 9	0,6044	0,602 9	0,602 3	0,601 7
0,56	—	—	0,616 6	0,613 8	0,611 2	0,609 8	0,608 6	0,606 1	0,6045	0,603 0	0,602 3	0,601 7
0,57	—	—	0,617 3	0,614 4	0,611 6	0,610 2	0,609 0	0,606 4	0,6047	0,603 1	0,602 4	0,601 7
0,58	—	—	0,618 0	0,615 0	0,612 1	0,610 6	0,609 3	0,606 6	0,6049	0,603 2	0,602 4	0,601 7
0,59	—	—	0,618 7	0,615 5	0,612 5	0,611 0	0,609 7	0,606 8	0,6050	0,603 2	0,602 4	0,601 6
0,60	—	—	0,619 4	0,616 1	0,613 0	0,611 4	0,610 0	0,607 0	0,6051	0,603 2	0,602 3	0,601 5
0,61	—	—	0,620 1	0,616 6	0,613 4	0,611 7	0,610 3	0,607 1	0,6051	0,603 1	0,602 3	0,601 4
0,62	—	—	0,620 7	0,617 1	0,613 8	0,612 0	0,610 5	0,607 2	0,6051	0,603 1	0,602 1	0,601 2
0,63	—	—	0,621 4	0,617 6	0,614 1	0,612 3	0,610 7	0,607 3	0,6051	0,602 9	0,601 9	0,601 0
0,64	—	—	0,622 0	0,618 1	0,614 4	0,612 5	0,610 9	0,607 3	0,6050	0,602 7	0,601 7	0,600 6
0,65	—	—	0,622 6	0,618 5	0,614 7	0,612 7	0,611 0	0,607 3	0,6048	0,602 4	0,601 3	0,600 3
0,66	—	—	0,623 1	0,618 9	0,614 9	0,612 8	0,611 0	0,607 2	0,6046	0,602 1	0,600 9	0,599 8
0,67	—	—	0,623 6	0,619 2	0,615 0	0,612 9	0,611 0	0,607 0	0,6043	0,601 7	0,600 4	0,599 3
0,68	—	—	0,624 0	0,619 4	0,615 1	0,612 9	0,610 9	0,606 7	0,6039	0,601 2	0,599 9	0,598 6
0,69	—	—	—	0,619 6	0,615 1	0,612 8	0,610 7	0,606 4	0,6035	0,600 5	0,599 2	0,597 9
0,70	—	—	—	0,619 7	0,615 0	0,612 6	0,610 5	0,605 9	0,6029	0,599 8	0,598 4	0,597 0
0,71	—	—	—	0,619 7	0,614 8	0,612 3	0,610 1	0,605 4	0,6022	0,599 0	0,597 5	0,596 1
0,72	—	—	—	0,619 6	0,614 5	0,611 9	0,609 6	0,604 7	0,6014	0,598 0	0,596 5	0,595 0
0,73	—	—	—	0,619 4	0,614 1	0,611 4	0,609 0	0,603 9	0,6004	0,596 9	0,595 3	0,593 7
0,74	—	—	—	0,619 1	0,613 6	0,610 8	0,608 3	0,602 9	0,5994	0,595 7	0,594 0	0,592 3
0,75	—	—	—	0,618 7	0,613 0	0,610 0	0,607 4	0,601 8	0,5981	0,594 3	0,592 5	0,590 8

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table 16 Orifice Plate with Flange Tappings — Discharge Coefficient, *C*, for $D = 375$ mm

Diameter ratio	Discharge coefficient, *C*, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 6	0,598 9	0,597 9	0,597 5	0,597 1	0,597 0	0,596 8	0,596 5	0,596 4	0,596 3	0,596 3	0,596 3
0,12	0,601 3	0,599 4	0,598 2	0,597 8	0,597 4	0,597 2	0,597 0	0,596 7	0,596 5	0,596 4	0,596 4	0,596 4
0,14	0,602 0	0,599 9	0,598 6	0,598 1	0,597 6	0,597 4	0,597 2	0,596 8	0,596 6	0,596 5	0,596 5	0,596 5
0,16	0,602 7	0,600 4	0,599 0	0,598 4	0,597 9	0,597 6	0,597 4	0,597 0	0,596 8	0,596 7	0,596 6	0,596 6
0,18	0,603 5	0,600 9	0,599 4	0,598 7	0,598 2	0,597 9	0,597 7	0,597 2	0,597 0	0,596 8	0,596 8	0,596 8
0,20	0,604 2	0,601 5	0,599 8	0,599 1	0,598 5	0,598 2	0,597 9	0,597 4	0,597 2	0,597 0	0,597 0	0,596 9
0,22	0,605 1	0,602 1	0,600 3	0,599 5	0,598 8	0,598 5	0,598 2	0,597 7	0,597 4	0,597 2	0,597 2	0,597 1
0,24	0,606 0	0,602 8	0,600 8	0,600 0	0,599 2	0,598 9	0,598 6	0,598 0	0,597 7	0,597 4	0,597 4	0,597 3
0,26	0,606 9	0,603 5	0,601 3	0,600 5	0,599 7	0,599 3	0,598 9	0,598 3	0,597 9	0,597 7	0,597 6	0,597 6
0,28	0,608 0	0,604 2	0,601 9	0,601 0	0,600 1	0,599 7	0,599 3	0,598 6	0,598 3	0,598 0	0,597 9	0,597 8
0,30	—	0,605 1	0,602 6	0,601 6	0,600 6	0,600 2	0,599 8	0,599 0	0,598 6	0,598 3	0,598 2	0,598 1
0,32	—	0,606 0	0,603 3	0,602 2	0,601 2	0,600 7	0,600 3	0,599 4	0,599 0	0,598 6	0,598 5	0,598 4
0,34	—	0,606 9	0,604 0	0,602 9	0,601 8	0,601 3	0,600 8	0,599 9	0,599 4	0,598 9	0,598 8	0,598 7
0,36	—	0,608 0	0,604 9	0,603 6	0,602 4	0,601 9	0,601 4	0,600 4	0,599 8	0,599 3	0,599 1	0,599 0
0,38	—	0,609 1	0,605 8	0,604 4	0,603 1	0,602 5	0,602 0	0,600 9	0,600 2	0,599 7	0,599 5	0,599 3
0,40	—	—	0,606 7	0,605 3	0,603 9	0,603 2	0,602 6	0,601 4	0,600 7	0,600 1	0,599 9	0,599 7
0,42	—	—	0,607 8	0,606 2	0,604 7	0,603 9	0,603 3	0,602 0	0,601 2	0,600 5	0,600 2	0,600 0
0,44	—	—	0,608 9	0,607 1	0,605 5	0,604 7	0,604 0	0,602 6	0,601 7	0,600 9	0,600 6	0,600 3
0,46	—	—	0,610 0	0,608 2	0,606 4	0,605 5	0,604 8	0,603 2	0,602 2	0,601 3	0,601 0	0,600 7
0,48	—	—	0,611 3	0,609 2	0,607 3	0,606 4	0,605 5	0,603 8	0,602 7	0,601 8	0,601 3	0,601 0
0,50	—	—	0,612 5	0,610 3	0,608 3	0,607 2	0,606 3	0,604 4	0,603 2	0,602 1	0,601 7	0,601 2
0,51	—	—	0,613 2	0,610 9	0,608 8	0,607 7	0,606 7	0,604 7	0,603 5	0,602 3	0,601 8	0,601 4
0,52	—	—	0,613 9	0,611 5	0,609 2	0,608 1	0,607 1	0,605 0	0,603 7	0,602 5	0,601 9	0,601 5
0,53	—	—	0,614 5	0,612 1	0,609 7	0,608 5	0,607 5	0,605 3	0,603 9	0,602 6	0,602 1	0,601 5
0,54	—	—	0,615 2	0,612 6	0,610 2	0,609 0	0,607 9	0,605 6	0,604 1	0,602 8	0,602 2	0,601 6
0,55	—	—	0,615 9	0,613 2	0,610 7	0,609 4	0,608 2	0,605 8	0,604 3	0,602 9	0,602 2	0,601 7
0,56	—	—	0,616 6	0,613 8	0,611 1	0,609 8	0,608 6	0,606 1	0,604 5	0,603 0	0,602 3	0,601 7
0,57	—	—	—	0,614 4	0,611 6	0,610 2	0,608 9	0,606 3	0,604 7	0,603 0	0,602 3	0,601 7
0,58	—	—	—	0,614 9	0,612 0	0,610 6	0,609 3	0,606 5	0,604 8	0,603 1	0,602 3	0,601 6
0,59	—	—	—	0,615 5	0,612 4	0,610 9	0,609 6	0,606 7	0,604 9	0,603 1	0,602 3	0,601 5
0,60	—	—	—	0,616 0	0,612 8	0,611 2	0,609 8	0,606 9	0,604 9	0,603 0	0,602 2	0,601 4
0,61	—	—	—	0,616 5	0,613 2	0,611 6	0,610 1	0,607 0	0,605 0	0,603 0	0,602 1	0,601 2
0,62	—	—	—	0,617 0	0,613 6	0,611 8	0,610 3	0,607 0	0,604 9	0,602 8	0,601 9	0,601 0
0,63	—	—	—	0,617 4	0,613 9	0,612 1	0,610 5	0,607 1	0,604 8	0,602 6	0,601 7	0,600 7
0,64	—	—	—	0,617 8	0,614 1	0,612 2	0,610 6	0,607 0	0,604 7	0,602 4	0,601 4	0,600 3
0,65	—	—	—	0,618 2	0,614 3	0,612 4	0,610 6	0,606 9	0,604 5	0,602 1	0,601 0	0,599 9
0,66	—	—	—	0,618 5	0,614 5	0,612 4	0,610 6	0,606 8	0,604 2	0,601 7	0,600 5	0,599 4
0,67	—	—	—	0,618 8	0,614 6	0,612 4	0,610 6	0,606 5	0,603 9	0,601 2	0,600 0	0,598 8
0,68	—	—	—	0,619 0	0,614 6	0,612 4	0,610 4	0,606 2	0,603 4	0,600 6	0,599 3	0,598 1
0,69	—	—	—	—	0,614 5	0,612 2	0,610 2	0,605 8	0,602 9	0,600 0	0,598 6	0,597 3
0,70	—	—	—	—	0,614 4	0,612 0	0,609 8	0,605 3	0,602 2	0,599 2	0,597 7	0,596 4
0,71	—	—	—	—	0,614 1	0,611 6	0,609 4	0,604 6	0,601 5	0,598 2	0,596 8	0,595 3
0,72	—	—	—	—	0,613 8	0,611 1	0,608 8	0,603 9	0,600 6	0,597 2	0,595 6	0,594 1
0,73	—	—	—	—	0,613 3	0,610 5	0,608 1	0,602 9	0,599 5	0,596 0	0,594 4	0,592 8
0,74	—	—	—	—	0,612 6	0,609 8	0,607 3	0,601 9	0,598 3	0,594 6	0,592 9	0,591 3
0,75	—	—	—	—	0,611 9	0,608 9	0,606 3	0,600 7	0,596 9	0,593 1	0,591 3	0,589 6

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table 17 Orifice Plate with Flange Tappings — Discharge Coefficient, *C*, for *D* = 760 mm

Diameter ratio	Discharge coefficient, *C*, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 6	0,599 0	0,597 9	0,597 5	0,597 2	0,597 0	0,596 9	0,596 6	0,596 4	0,596 3	0,596 3	0,596 3
0,12	0,601 3	0,599 4	0,598 3	0,597 8	0,597 4	0,597 2	0,597 0	0,596 7	0,596 5	0,596 4	0,596 4	0,596 4
0,14	0,602 0	0,599 9	0,598 6	0,598 1	0,597 7	0,597 4	0,597 2	0,596 9	0,596 7	0,596 6	0,596 6	0,596 5
0,16	0,602 8	0,600 5	0,599 0	0,598 5	0,597 9	0,597 7	0,597 5	0,597 1	0,596 9	0,596 7	0,596 7	0,596 7
0,18	0,603 5	0,601 0	0,599 4	0,598 8	0,598 2	0,598 0	0,597 7	0,597 3	0,597 0	0,596 9	0,596 9	0,596 8
0,20	—	0,601 6	0,599 9	0,599 2	0,598 6	0,598 3	0,598 0	0,597 5	0,597 3	0,597 1	0,597 1	0,597 0
0,22	—	0,602 2	0,600 4	0,599 6	0,598 9	0,598 6	0,598 3	0,597 8	0,597 5	0,597 3	0,597 3	0,597 2
0,24	—	0,602 9	0,600 9	0,600 1	0,599 3	0,599 0	0,598 7	0,598 1	0,597 8	0,597 6	0,597 5	0,597 5
0,26	—	0,603 6	0,601 4	0,600 6	0,599 8	0,599 4	0,599 1	0,598 4	0,598 1	0,597 8	0,597 7	0,597 7
0,28	—	—	0,602 0	0,601 1	0,600 3	0,599 8	0,599 5	0,598 8	0,598 4	0,598 1	0,598 0	0,598 0
0,30	—	—	0,602 7	0,601 7	0,600 8	0,600 3	0,599 9	0,599 2	0,598 7	0,598 4	0,598 3	0,598 2
0,32	—	—	0,603 4	0,602 3	0,601 3	0,600 8	0,600 4	0,599 6	0,599 1	0,598 7	0,598 6	0,598 5
0,34	—	—	0,604 2	0,603 0	0,602 0	0,601 4	0,601 0	0,600 0	0,599 5	0,599 1	0,599 0	0,598 8
0,36	—	—	0,605 0	0,603 8	0,602 6	0,602 0	0,601 5	0,600 5	0,599 9	0,599 5	0,599 3	0,599 2
0,38	—	—	0,605 9	0,604 6	0,603 3	0,602 7	0,602 1	0,601 0	0,600 4	0,599 9	0,599 7	0,599 5
0,40	—	—	—	0,605 4	0,604 1	0,603 4	0,602 8	0,601 6	0,600 9	0,600 3	0,600 0	0,599 8
0,42	—	—	—	0,606 4	0,604 9	0,604 1	0,603 5	0,602 2	0,601 4	0,600 7	0,600 4	0,600 2
0,44	—	—	—	0,607 3	0,605 7	0,604 9	0,604 2	0,602 7	0,601 9	0,601 1	0,600 8	0,600 5
0,46	—	—	—	0,608 4	0,606 6	0,605 7	0,604 9	0,603 4	0,602 4	0,601 5	0,601 2	0,600 8
0,48	—	—	—	0,609 4	0,607 5	0,606 5	0,605 7	0,604 0	0,602 9	0,601 9	0,601 5	0,601 1
0,50	—	—	—	—	0,608 4	0,607 4	0,606 5	0,604 6	0,603 4	0,602 3	0,601 8	0,601 4
0,51	—	—	—	—	0,608 9	0,607 8	0,606 9	0,604 9	0,603 6	0,602 5	0,602 0	0,601 5
0,52	—	—	—	—	0,609 4	0,608 2	0,607 3	0,605 2	0,603 9	0,602 6	0,602 1	0,601 6
0,53	—	—	—	—	0,609 9	0,608 7	0,607 6	0,605 4	0,604 1	0,602 8	0,602 2	0,601 7
0,54	—	—	—	—	0,610 3	0,609 1	0,608 0	0,605 7	0,604 3	0,602 9	0,602 3	0,601 7
0,55	—	—	—	—	0,610 8	0,609 5	0,608 4	0,606 0	0,604 4	0,603 0	0,602 4	0,601 8
0,56	—	—	—	—	0,611 2	0,609 9	0,608 7	0,606 2	0,604 6	0,603 1	0,602 4	0,601 8
0,57	—	—	—	—	0,611 7	0,610 3	0,609 0	0,606 4	0,604 7	0,603 1	0,602 4	0,601 7
0,58	—	—	—	—	0,612 1	0,610 6	0,609 3	0,606 6	0,604 8	0,603 1	0,602 4	0,601 7
0,59	—	—	—	—	0,612 5	0,611 0	0,609 6	0,606 8	0,604 9	0,603 1	0,602 3	0,601 6
0,60	—	—	—	—	0,612 9	0,611 3	0,609 9	0,606 9	0,605 0	0,603 1	0,602 2	0,601 4
0,61	—	—	—	—	0,613 2	0,611 6	0,610 1	0,607 0	0,605 0	0,603 0	0,602 1	0,601 2
0,62	—	—	—	—	0,613 6	0,611 8	0,610 3	0,607 0	0,604 9	0,602 8	0,601 9	0,601 0
0,63	—	—	—	—	—	0,612 0	0,610 4	0,607 0	0,604 8	0,602 6	0,601 6	0,600 6
0,64	—	—	—	—	—	0,612 2	0,610 5	0,606 9	0,604 6	0,602 3	0,601 3	0,600 3
0,65	—	—	—	—	—	0,612 3	0,610 5	0,606 8	0,604 4	0,602 0	0,600 9	0,599 8
0,66	—	—	—	—	—	0,612 3	0,610 5	0,606 6	0,604 1	0,601 5	0,600 4	0,599 2
0,67	—	—	—	—	—	0,612 3	0,610 4	0,606 3	0,603 7	0,601 0	0,599 8	0,598 6
0,68	—	—	—	—	—	0,612 2	0,610 2	0,606 0	0,603 2	0,600 4	0,599 1	0,597 9
0,69	—	—	—	—	—	0,611 9	0,609 9	0,605 5	0,602 6	0,599 6	0,598 3	0,597 0
0,70	—	—	—	—	—	0,611 6	0,609 5	0,604 9	0,601 9	0,598 8	0,597 4	0,596 0
0,71	—	—	—	—	—	0,611 2	0,609 0	0,604 2	0,601 0	0,597 8	0,596 3	0,594 9
0,72	—	—	—	—	—	0,610 7	0,608 4	0,603 4	0,600 1	0,596 7	0,595 1	0,593 6
0,73	—	—	—	—	—	0,610 0	0,607 6	0,602 4	0,598 9	0,595 4	0,593 8	0,592 2
0,74	—	—	—	—	—	—	0,606 7	0,601 2	0,597 6	0,594 0	0,592 3	0,590 6
0,75	—	—	—	—	—	—	0,605 6	0,599 9	0,596 2	0,592 3	0,590 6	0,588 8

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table 18 Orifice Plate with Flange Tappings — Discharge Coefficient, *C*, for *D* = 1 000 mm

Diameter ratio	Discharge coefficient, *C*, for Re_D equal to											
β	5×10^3	1×10^4	2×10^4	3×10^4	5×10^4	7×10^4	1×10^5	3×10^5	1×10^6	1×10^7	1×10^8	∞
0,10	0,600 6	0,599 0	0,598 0	0,597 6	0,597 2	0,597 0	0,596 9	0,596 6	0,596 4	0,596 3	0,596 3	0,596 3
0,12	0,601 3	0,599 4	0,598 3	0,597 8	0,597 4	0,597 2	0,597 0	0,596 7	0,596 6	0,596 5	0,596 4	0,596 4
0,14	0,602 0	0,599 9	0,598 7	0,598 1	0,597 7	0,597 4	0,597 3	0,596 9	0,596 7	0,596 6	0,596 6	0,596 6
0,16	0,602 8	0,600 5	0,599 0	0,598 5	0,598 0	0,597 7	0,597 5	0,597 1	0,596 9	0,596 7	0,596 7	0,596 7
0,18	—	0,601 0	0,599 5	0,598 8	0,598 3	0,598 0	0,597 7	0,597 3	0,597 1	0,596 9	0,596 9	0,596 9
0,20	—	0,601 6	0,599 9	0,599 2	0,598 6	0,598 3	0,598 0	0,597 5	0,597 3	0,597 1	0,597 1	0,597 1
0,22	—	0,602 2	0,600 4	0,599 6	0,599 0	0,598 6	0,598 4	0,597 8	0,597 5	0,597 3	0,597 3	0,597 3
0,24	—	0,602 9	0,600 9	0,600 1	0,599 4	0,599 0	0,598 7	0,598 1	0,597 8	0,597 6	0,597 5	0,597 5
0,26	—	—	0,601 5	0,600 6	0,599 8	0,599 4	0,599 1	0,598 4	0,598 1	0,597 9	0,597 8	0,597 7
0,28	—	—	0,602 1	0,601 2	0,600 3	0,599 9	0,599 5	0,598 8	0,598 4	0,598 1	0,598 1	0,598 0
0,30	—	—	0,602 7	0,601 7	0,600 8	0,600 4	0,600 0	0,599 2	0,598 8	0,598 5	0,598 3	0,598 3
0,32	—	—	0,603 5	0,602 4	0,601 4	0,600 9	0,600 5	0,599 6	0,599 2	0,598 8	0,598 7	0,598 6
0,34	—	—	0,604 3	0,603 1	0,602 0	0,601 5	0,601 0	0,600 1	0,599 6	0,599 1	0,599 0	0,598 9
0,36	—	—	—	0,603 8	0,602 7	0,602 1	0,601 6	0,600 6	0,600 0	0,599 5	0,599 4	0,599 2
0,38	—	—	—	0,604 6	0,603 4	0,602 7	0,602 2	0,601 1	0,600 5	0,599 9	0,599 7	0,599 5
0,40	—	—	—	0,605 5	0,604 1	0,603 4	0,602 8	0,601 6	0,600 9	0,600 3	0,600 1	0,599 9
0,42	—	—	—	0,606 4	0,604 9	0,604 2	0,603 5	0,602 2	0,601 4	0,600 7	0,600 5	0,600 2
0,44	—	—	—	—	0,605 8	0,605 0	0,604 3	0,602 8	0,601 9	0,601 2	0,600 9	0,600 6
0,46	—	—	—	—	0,606 7	0,605 8	0,605 0	0,603 4	0,602 4	0,601 6	0,601 2	0,600 9
0,48	—	—	—	—	0,607 6	0,606 6	0,605 8	0,604 0	0,603 0	0,602 0	0,601 6	0,601 2
0,50	—	—	—	—	0,608 5	0,607 5	0,606 5	0,604 6	0,603 5	0,602 4	0,601 9	0,601 5
0,51	—	—	—	—	0,609 0	0,607 9	0,606 9	0,604 9	0,603 7	0,602 5	0,602 0	0,601 6
0,52	—	—	—	—	0,609 5	0,608 3	0,607 3	0,605 2	0,603 9	0,602 7	0,602 2	0,601 7
0,53	—	—	—	—	0,609 9	0,608 7	0,607 7	0,605 5	0,604 1	0,602 8	0,602 3	0,601 7
0,54	—	—	—	—	0,610 4	0,609 1	0,608 1	0,605 8	0,604 3	0,603 0	0,602 4	0,601 8
0,55	—	—	—	—	—	0,609 6	0,608 4	0,606 0	0,604 5	0,603 1	0,602 4	0,601 8
0,56	—	—	—	—	—	0,609 9	0,608 8	0,606 3	0,604 7	0,603 1	0,602 5	0,601 8
0,57	—	—	—	—	—	0,610 3	0,609 1	0,606 5	0,604 8	0,603 2	0,602 5	0,601 8
0,58	—	—	—	—	—	0,610 7	0,609 4	0,606 7	0,604 9	0,603 2	0,602 4	0,601 7
0,59	—	—	—	—	—	0,611 0	0,609 7	0,606 8	0,605 0	0,603 2	0,602 4	0,601 6
0,60	—	—	—	—	—	0,611 3	0,609 9	0,606 9	0,605 0	0,603 1	0,602 3	0,601 5
0,61	—	—	—	—	—	0,611 6	0,610 2	0,607 0	0,605 0	0,603 0	0,602 1	0,601 3
0,62	—	—	—	—	—	0,611 9	0,610 3	0,607 1	0,604 9	0,602 9	0,601 9	0,601 0
0,63	—	—	—	—	—	0,612 1	0,610 5	0,607 0	0,604 8	0,602 6	0,601 6	0,600 7
0,64	—	—	—	—	—	0,612 2	0,610 6	0,607 0	0,604 7	0,602 3	0,601 3	0,600 3
0,65	—	—	—	—	—	—	0,610 6	0,606 8	0,604 4	0,602 0	0,600 9	0,599 8
0,66	—	—	—	—	—	—	0,610 5	0,606 6	0,604 1	0,601 6	0,600 4	0,599 3
0,67	—	—	—	—	—	—	0,610 4	0,606 3	0,603 7	0,601 0	0,599 8	0,598 6
0,68	—	—	—	—	—	—	0,610 2	0,606 0	0,603 2	0,600 4	0,599 1	0,597 9
0,69	—	—	—	—	—	—	0,609 9	0,605 5	0,602 6	0,599 7	0,598 3	0,597 0
0,70	—	—	—	—	—	—	0,609 5	0,604 9	0,601 9	0,598 8	0,597 4	0,596 0
0,71	—	—	—	—	—	—	0,609 0	0,604 2	0,601 0	0,597 8	0,596 3	0,594 9
0,72	—	—	—	—	—	—	0,608 4	0,603 3	0,600 0	0,596 7	0,595 1	0,593 6
0,73	—	—	—	—	—	—	0,607 6	0,602 4	0,598 9	0,595 4	0,593 8	0,592 2
0,74	—	—	—	—	—	—	0,606 6	0,601 2	0,597 6	0,593 9	0,592 2	0,590 6
0,75	—	—	—	—	—	—	0,605 5	0,599 9	0,596 1	0,592 3	0,590 5	0,588 7

NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.

Table 19 Orifice Plates — Expansibility (Expansion) Factor, ε

Diameter ratio		Expansibility [expansion] factor, ε, for p_2/p_1 equal to							
β	β^4	0,98	0,96	0,94	0,92	0,90	0,85	0,80	0,75
for κ = 1,2									
0,100 0	0,000 1	0,994 1	0,988 3	0,982 4	0,976 4	0,970 5	0,955 5	0,940 4	0,925 2
0,562 3	0,100 0	0,993 6	0,987 1	0,980 6	0,974 1	0,967 6	0,951 1	0,934 5	0,917 7
0,668 7	0,200 0	0,992 7	0,985 3	0,977 9	0,970 5	0,963 1	0,944 3	0,925 4	0,906 3
0,740 1	0,300 0	0,991 5	0,982 9	0,974 3	0,965 7	0,957 0	0,935 2	0,913 2	0,891 0
0,750 0	0,316 4	0,991 2	0,982 4	0,973 6	0,964 8	0,955 9	0,933 5	0,910 9	0,888 1
for κ = 1,3									
0,100 0	0,000 1	0,994 6	0,989 1	0,983 7	0,978 2	0,972 7	0,958 7	0,944 6	0,930 3
0,562 3	0,100 0	0,994 0	0,988 1	0,982 1	0,976 0	0,970 0	0,954 7	0,939 1	0,923 4
0,668 7	0,200 0	0,993 2	0,986 4	0,979 6	0,972 7	0,965 8	0,948 4	0,930 7	0,912 8
0,740 1	0,300 0	0,992 1	0,984 2	0,976 2	0,968 2	0,960 2	0,939 9	0,919 3	0,898 5
0,750 0	0,316 4	0,991 9	0,983 8	0,975 6	0,967 4	0,959 1	0,938 3	0,917 2	0,895 8
for κ = 1,4									
0,100 0	0,000 1	0,995 0	0,989 9	0,984 8	0,979 7	0,974 6	0,961 5	0,948 3	0,934 8
0,562 3	0,100 0	0,994 5	0,988 9	0,983 3	0,977 7	0,972 0	0,957 7	0,943 1	0,928 3
0,668 7	0,200 0	0,993 7	0,987 4	0,981 0	0,974 6	0,968 1	0,951 8	0,935 3	0,918 4
0,740 1	0,300 0	0,992 7	0,985 3	0,977 9	0,970 4	0,962 9	0,943 9	0,924 6	0,905 0
0,750 0	0,316 4	0,992 5	0,984 9	0,977 3	0,969 6	0,961 9	0,942 4	0,922 6	0,902 5
for κ = 1,66									
0,100 0	0,000 1	0,995 8	0,991 5	0,987 2	0,982 8	0,978 4	0,967 3	0,955 8	0,944 1
0,562 3	0,100 0	0,995 3	0,990 6	0,985 9	0,981 1	0,976 3	0,964 0	0,951 5	0,938 6
0,668 7	0,200 0	0,994 7	0,989 3	0,983 9	0,978 5	0,973 0	0,959 0	0,944 7	0,930 1
0,740 1	0,300 0	0,993 8	0,987 6	0,981 3	0,974 9	0,968 5	0,952 3	0,935 7	0,918 6
0,750 0	0,316 4	0,993 6	0,987 2	0,980 8	0,974 3	0,967 7	0,951 0	0,934 0	0,916 4
NOTE This table is given for convenience. The values given are not intended for precise interpolation. Extrapolation is not permitted.									

ANNEX B

(*Foreword* and *Clause* 12.1)

FLOW CONDITIONERS

B-1 GENERAL

This Annex describes some patented flow conditioners which can be used upstream of orifice plates and the requirements for straight lengths associated with them. It describes the Gallagher flow conditioner and NOVA's design of K-Lab perforated plate flow conditioner. It gives the situations in which the flow conditioners have passed the compliance test and can be used downstream of any upstream fitting. It is not intended that the inclusion of the flow conditioners described here should limit the use of other flow conditioner designs which have been tested and proved to provide sufficiently small shifts in discharge coefficient. These flow conditioners, available commercially, are given as examples of devices which have passed the compliance test. This information is given for the convenience of users and does not constitute an endorsement by the standard of this product.

B-2 GALLAGHER FLOW CONDITIONER — COMPLIANCE TESTING

B-2.1 The Gallagher flow conditioner shown in Fig. 13 meets the compliance test given in this standard and can be used downstream of any fitting provided that it meets the required manufacturing specification (which shall be obtained from the patent holder) and is installed in accordance with **B-2.3**.

B-2.2 The Gallagher flow conditioner is covered by an existing patent. It consists of an anti-swirl device, a settling chamber and lastly a profile device as shown in Fig. 14).

The pressure loss coefficient, *K*, for the Gallagher flow conditioner depends on the manufacturing specification of the conditioner; it is approximately equal to 2, where *K* is given by the following equation:

$$K = \frac{\Delta P_c}{\frac{1}{2}\rho v^2}$$

where ΔP_c is the pressure loss across the Gallagher flow conditioner and *v* is the mean axial velocity of the fluid in the pipe.

B-2.3 L_f, the distance between the orifice plate and the nearest upstream fitting, is at least equal to 17*D*. The Gallagher flow conditioner is installed so that L_s, the distance between the downstream end of the Gallagher flow conditioner and the orifice plate, is such that

$$5D \leq L_s \leq L_f - 8D$$

In this location, the Gallagher flow conditioner can be used for $\beta \leq 0.67$.

If $0.67 \leq \beta \leq 0.75$, the location of the Gallagher flow conditioner is more restricted, and L_s is equal to

$$7D \pm D$$

In this location, the Gallagher flow conditioner has satisfied in **7.4.1.7** of ISO 5167-1 for $\beta = 0.75$.

The distance to a bend (or bend combination) or a tee is measured to the downstream end of the curved portion of the nearest (or only) bend or of the tee. The distance to a reducer or expander is measured to the downstream end of the curved or conical portion of the reducer or expander.

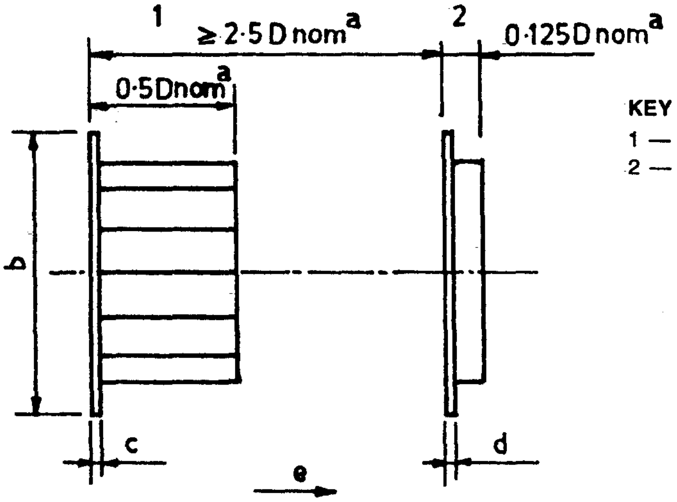
The locations given in this clause are acceptable downstream of any fitting. A wider range of locations for the Gallagher flow conditioner is permissible if the range of upstream fittings is restricted or the overall length between the upstream fitting and the orifice plate is increased or the diameter ratio of the orifice plate is reduced. These locations are not described here.

B-3 NOVA'S DESIGN OF K-LAB PERFORATED PLATE FLOW CONDITIONER — COMPLIANCE TESTING

B-3.1 NOVA's design of K-Lab perforated plate flow conditioner, known as the K-Lab NOVA flow conditioner, shown in Fig. 15 meets the compliance test of this standard and can be used downstream of any fitting provided that it meets the manufacturing specification in **B-3.2** and **B-3.3** and is installed in accordance with **B-3.4**.

B-3.2 The K-Lab NOVA flow conditioner consists of a plate with 25 bored holes arranged in a symmetrical circular pattern as shown in Fig. 15. The dimensions of the holes are a function of the pipe inside diameter, *D*, and depend on the pipe Reynolds number. The hole locations for $Re_D \geq 10^5$ are given in **B-3.3**.

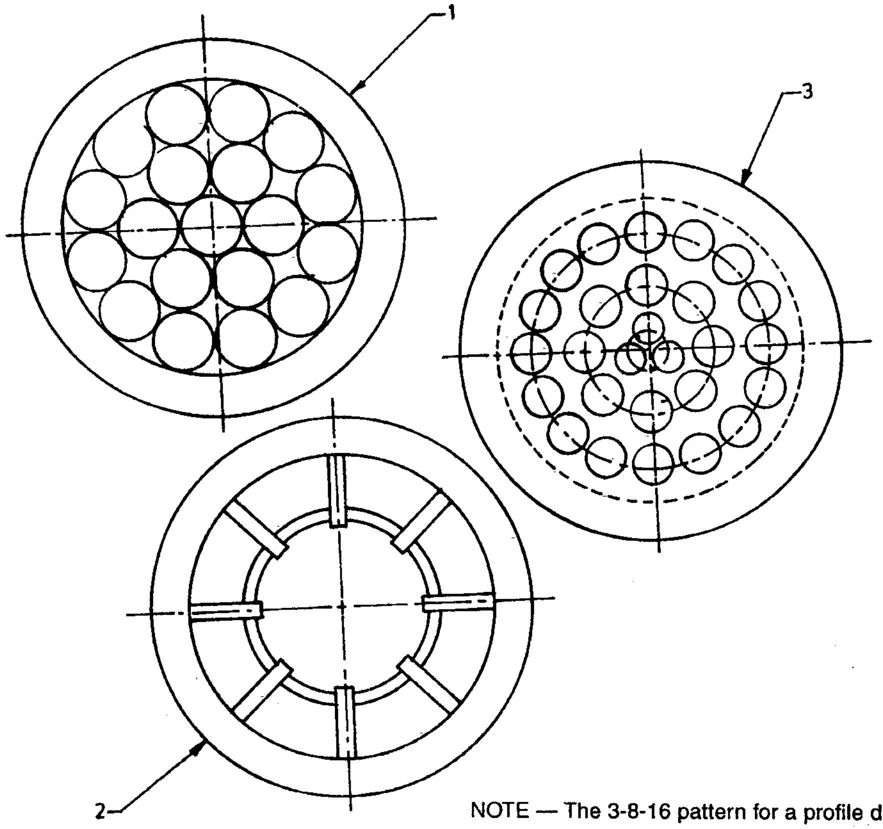
The perforated plate thickness, t_c is such that



KEY

1 — anti-swirl device
2 — profile device
a = D_{nom} is the nominal pipe diameter
b = length equal to diameter of raised face
c = 3.2 mm for D_{nom} = 50 mm to 75 mm tube style
6.4 mm for D_{nom} = 100 mm to 450 mm tube style
12.7 mm for D_{nom} = 500 mm to 600 mm tube style
12.7 mm for D_{nom} = 50 mm to 300 mm vane style
17.1 mm for D_{nom} = 350 mm to 600 mm vane style
d = 3.2 mm for D_{nom} = 50 mm to 75 mm
6.4 mm for D_{nom} = 100 mm to 450 mm
12.7 mm for D_{nom} = 500 mm to 600 mm
e = direction of flow

FIG. 13 TYPICAL ARRANGEMENT OF GALLAGHER FLOW CONDITIONER



KEY

1 — anti-swirl device-tube style option: 19-tube uniform concentric bundle (it may be pin-mounted)

2 — anti-swirl device-vane style option: 8 vanes of length 0.125*D* to 0.25*D*, concentric with the pipe (the device may be placed at the entrance to the meter run)

3 — profile device: 3-8-16 pattern (*see* Note)

NOTE — The 3-8-16 pattern for a profile device is:

a) 3 holes on pitch circle diameter 0.15*D* to 0.155*D*; their diameter is such that the sum of their areas is 3 percent to 5 percent of the pipe area;

b) 8 holes on pitch circle diameter 0.44*D* to 0.48*D*; their diameter is such that the sum of their areas is 19 percent to 21 percent of the pipe area; and

c) 16 holes on pitch circle diameter 0.81*D* to 0.85*D*; their diameter is such that the sum of their areas is 25 percent to 29 percent of the pipe area.

FIG. 14 TYPICAL COMPONENTS OF GALLAGHER FLOW CONDITIONER (FACE VIEWS)

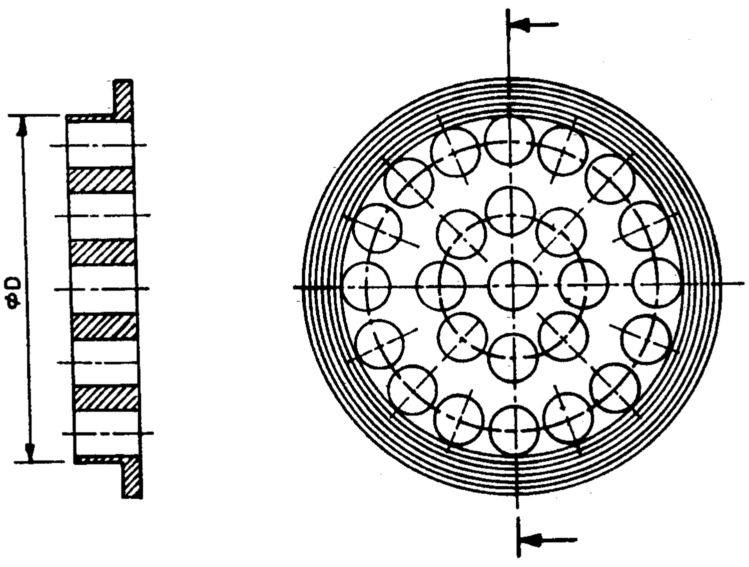


FIG. 15 THE K-LAB NOVA FLOW CONDITIONER

$0.125D \le t_c \le 0.15D$. The flange thickness depends on the application; the outer diameter and flange face surface depend on the flange type and the application.

The pressure loss coefficient, K, for the K-Lab NOVA flow conditioner is approximately equal to 2, where K is given by the following equation:

$$K = \frac{\Delta P_c}{\frac{1}{2}\rho v^2}$$

where

ΔP_c = pressure loss across the K-Lab NOVA flow conditioner;

ρ = density of the fluid in the pipe; and

v = mean axial velocity of the fluid in the pipe.

B-3.3 Hole Locations

B-3.3.1 Provided that Re_D ~ 8 × 105, there are:

a) a central hole of diameter 0.186 29D ± 0.000 77D,

b) a ring of 8 holes of diameter 0.163D ± 0.000 77D on a pitch circle diameter of 0.5D ± 0.5 mm, and

c) a ring of 16 holes of diameter 0.120 3D ± 0.000 77D on a pitch circle diameter of 0.85D ± 0.5 mm.

B-3.3.2 Provided that 8 × 105 > Re_D ~ 105, there are:

a) a central hole of diameter 0.226 64D ± 0.000 77D,

b) a ring of 8 holes of diameter 0.163 09D ± 0.000 77D on a pitch circle diameter of 0.5D ± 0.5 mm, and

c) a ring of 16 holes of diameter 0.124 22D ± 0.000 77D on a pitch circle diameter of 0.85D ± 0.5 mm.

B-3.4 L_f the distance between the orifice plate and the nearest upstream fitting, is at least equal to 17D. The K-Lab NOVA flow conditioner is installed so that L_s, the distance between the downstream end of the K-Lab NOVA flow conditioner and the orifice plate, is such that

$$8.5D \le L_s \le L_f - 7.5D$$

The K-Lab NOVA flow conditioner can be used for $\beta \le 0.67$.

The distance to a bend (or bend combination) or a tee is measured to the downstream end of the curved portion of the nearest (or only) bend or of the tee. The distance to a reducer or expander is measured to the downstream end of the curved or conical portion of the reducer or the expander.

The locations given in this subclause are acceptable downstream of any fitting. A wider range of locations for the K-Lab NOVA flow conditioner is permissible if the range of upstream fittings is restricted or the overall length between the upstream fitting and the orifice plate is increased or the diameter ratio of the orifice plate is reduced. These locations are not described here.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 1986 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards : Monthly Additions'.

This Indian Standard has been developed from Doc : No. PG 26 (1017).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters :

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002
Telephones : 2323 01 31, 2323 33 75, 2323 94 02

Telegrams : Manaksanstha
(Common to all offices)

Regional Offices :

		Telephone
Central	: Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110 002	2323 76 17 2323 38 41
Eastern	: 1/14 C.I.T. Scheme VII M, V. I. P. Road, Kankurgachi KOLKATA 700 054	2337 84 99, 2337 85 61 2337 86 26, 2337 91 20
Northern	: SCO 335-336, Sector 34-A, CHANDIGARH 160 022	260 38 43 260 92 85
Southern	: C.I.T. Campus, IV Cross Road, CHENNAI 600 113	2254 12 16, 2254 14 42 2254 25 19, 2254 23 15
Western	: Manakalaya, E9 MIDC, Marol, Andheri (East) MUMBAI 400 093	2832 92 95, 2832 78 58 2832 78 91, 2832 78 92

Branches : AHMEDABAD. BANGALORE. BHOPAL. BHUBANESHWAR. COIMBATORE. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. KANPUR. LUCKNOW. NAGPUR. NALAGARH. PATNA. PUNE. RAJKOT. THIRUVANANTHAPURAM. VISAKHAPATNAM.

Printed at Prabhat Offset Press, New Delhi-2

AMENDMENT NO. 1 DECEMBER 2007
TO
IS 15675 : 2006 FLOW MEASUREMENT OF NATURAL GAS AND FLUIDS BY ORIFICE PLATE METERS

(*Foreword, third para, line* 4) — Substitute 'American Gas Association' *for* 'American gas authority'.

(PG 26)

Reprography Unit, BIS, New Delhi, India